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RNAV PROCEDURAL TURN ANTICIPATION TECHNIQUES EXPERIMENT NUMBER --ETC(U)
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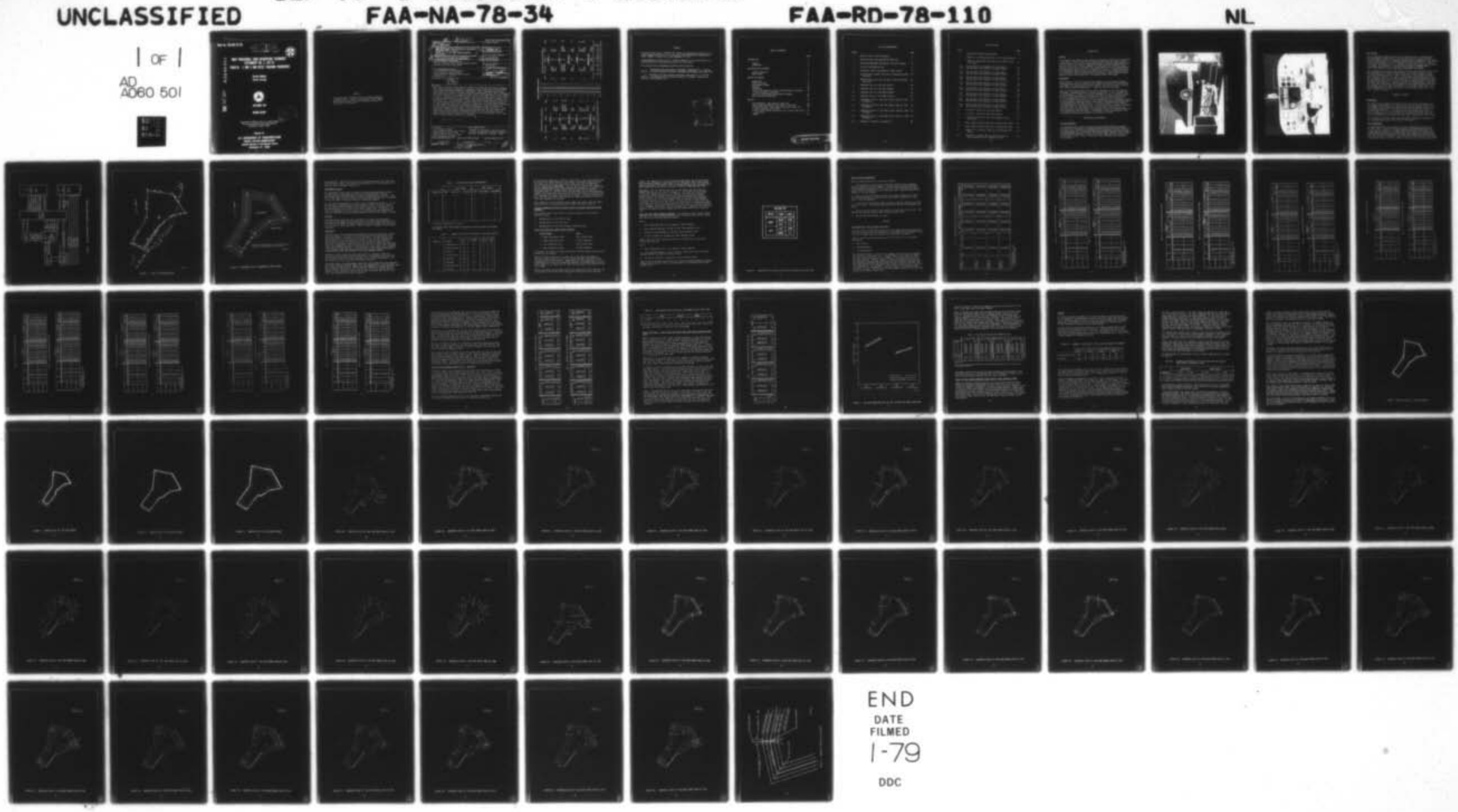

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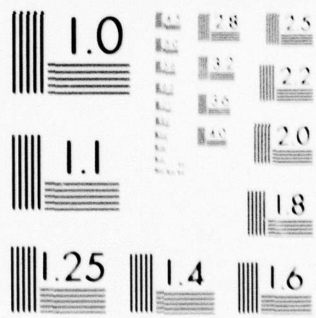

MICROCOPY RESOLUTION TEST CHART

Report No. FAA-RD-78-110

LEVEL II

RNAV PROCEDURAL TURN ANTICIPATION TECHNIQUES
EXPERIMENT NO. 2, GAT-2A
PHASE III - 2 AND 4 NMI OFFSET TRACKING PROCEDURES

Bernard Goldberg
Donald Eldredge

SEPTEMBER 1978

INTERIM REPORT

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16. Abstract

This Phase III report is the last of a series of interim and data reports dealing with offsets and turn anticipation techniques using a single waypoint analog RNAV system and a noncentered needle CDI instrument. Eight instrument rated pilots participated in a series of flight simulation tests employing solo pilot techniques which were conducted at the National Aviation Facilities Experimental Center (NAFEC) in order to measure total system crosstrack (TSCT) and flight technical error (FTE) as well as operational pilot performance. The tests were designed to assess pilot performance for: (1) anticipation of turns while maintaining a desired offset, and (2) steady state parallel offset tracking proficiency. Performance was measured on these variables: horizontal tracking, airspeed control and procedural performance. The horizontal tracking data included both steady state (parallel offset) and transition (parallel offset) data. The major findings of this study were: (1) No significant differences exist between the offset turn data and the offset steady state data in terms of TSCT or FTE magnitude; and (2) The procedures used for shallow angle turns (29° and 48°) and the logic for the interception of the final approach course have a potential for blunders.

(29 DEG AND 48 DEG)

17. Key Words	18. Distribution Statement
Area Navigation (RNAV) Total System Crosstrack Error (TSCT) Flight Technical Error (FTE) Course Deviation Indicator (CDI) Omni Bearing Sector (OBS)	Document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161

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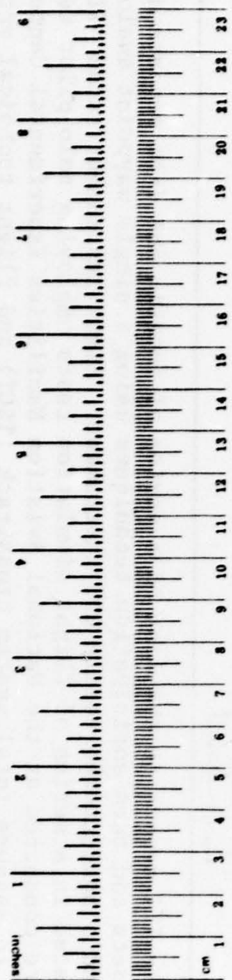
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F

PREFACE

The data in this report represent the results of experiments conducted in the Cockpit Simulation Facility at the National Aviation Facilities Experimental Center (NAFEC), between July 25 and September 13, 1977.

Acknowledgement is given to Mr. D. Timoteo, ANA-751, for his contribution to reducing the data and preparing the plots for this effort.

This interim report supplements previous reports entitled:

1. "Procedural Turn Anticipation Techniques, Experiment No. 2, GAT-2A, Phase I - On Course Tracking" by Messrs. Eldredge and Goldberg, dated July 1977.

2. "Procedural Turn Anticipation Techniques, Experiment No. 2, GAT-2A, Phase II - Preliminary Offset Tracking Procedures" by Messrs. Eldredge and Goldberg, dated November 1977.

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INTRODUCTION

PURPOSE.

The purpose of the Phase III data collection simulation effort was to establish a data base on 2 and 4 nautical mile (nmi) offsets (left and right) using a specific logic for setting the Omni Bearing Selector (OBS) during offset tracking, and for the use of pilot judgment of Course Deviation Indicator (CDI) distance (and/or rate of movement) for transitioning to the next segment while maintaining the desired offset. In addition, the use of a specific procedure for intercepting the final approach course (from an offset configuration) was also evaluated. These procedures were tested using a single waypoint analog general aviation RNAV system and a noncentered needle CDI display.

BACKGROUND.

This activity is one of several projects conducted by the Federal Aviation Administration in order to assist in the orderly introduction of Area Navigation (RNAV) into the National Airspace System. This interim report is one of three reports covering experiments on turn anticipation procedures.

Based on the preceding Phase II data report ("Procedural Turn Anticipation Techniques - Preliminary Offset Tracking Procedures"), it was concluded that it was necessary to conduct a detailed experiment in order to expand the data base for offset tracking and to evaluate the use of a noncentered CDI non-to fly and maintain 2 and 4 nmi offsets in a terminal area environment. In the preceding effort (Phase II), it was determined that no adequate procedural turn anticipation technique existed (when using a noncentered CDI needle) for transitioning from the offset course, to the final approach course without incurring excessive crosstrack errors. It was, therefore, necessary to develop a specific logic for intercepting the final approach course prior to the Phase III data collection effort. The necessary logic was developed, based on the tracking data from the Phase II experiment, and was incorporated in the experimental design and procedures for the Phase III study.

DESCRIPTION OF EQUIPMENT

COCKPIT SIMULATOR.

All testing was done using the Singer-Link GAT-2A/Xerox XDS-530A computer facility which represents a twin-engine, general aviation aircraft (figure 1). For these tests, the GAT-2A was equipped with conventional instruments, dual Navigation/Communication (NAV/COM), King KNC-610 RNAV computer, and a standard Course Deviation indicator. There was no slant range correction feature in the equipment tested. Figure 2 shows how these equipments were installed in the GAT-2A.

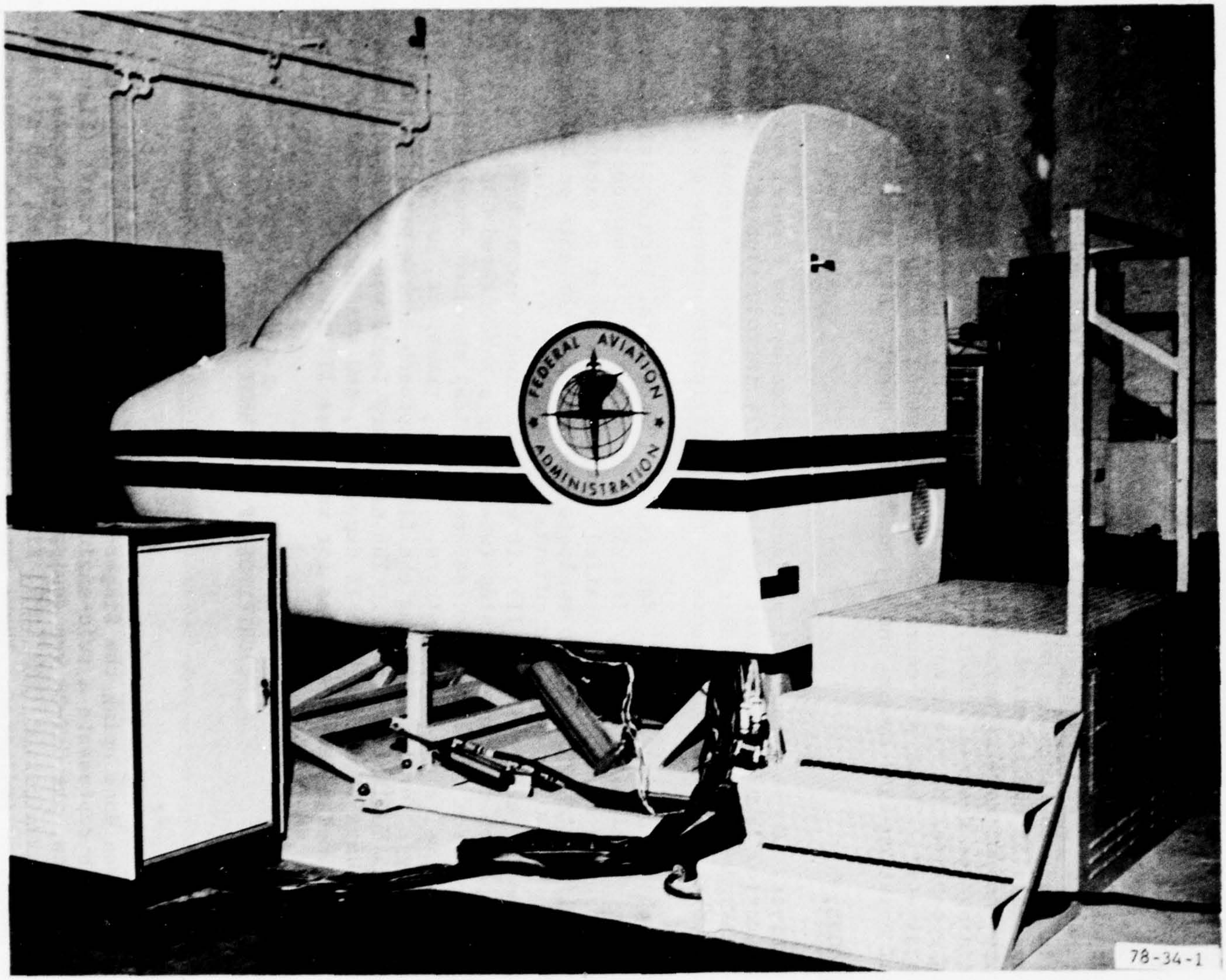

FIGURE 1. EXTERIOR VIEW-GAT-2A SIMULATOR

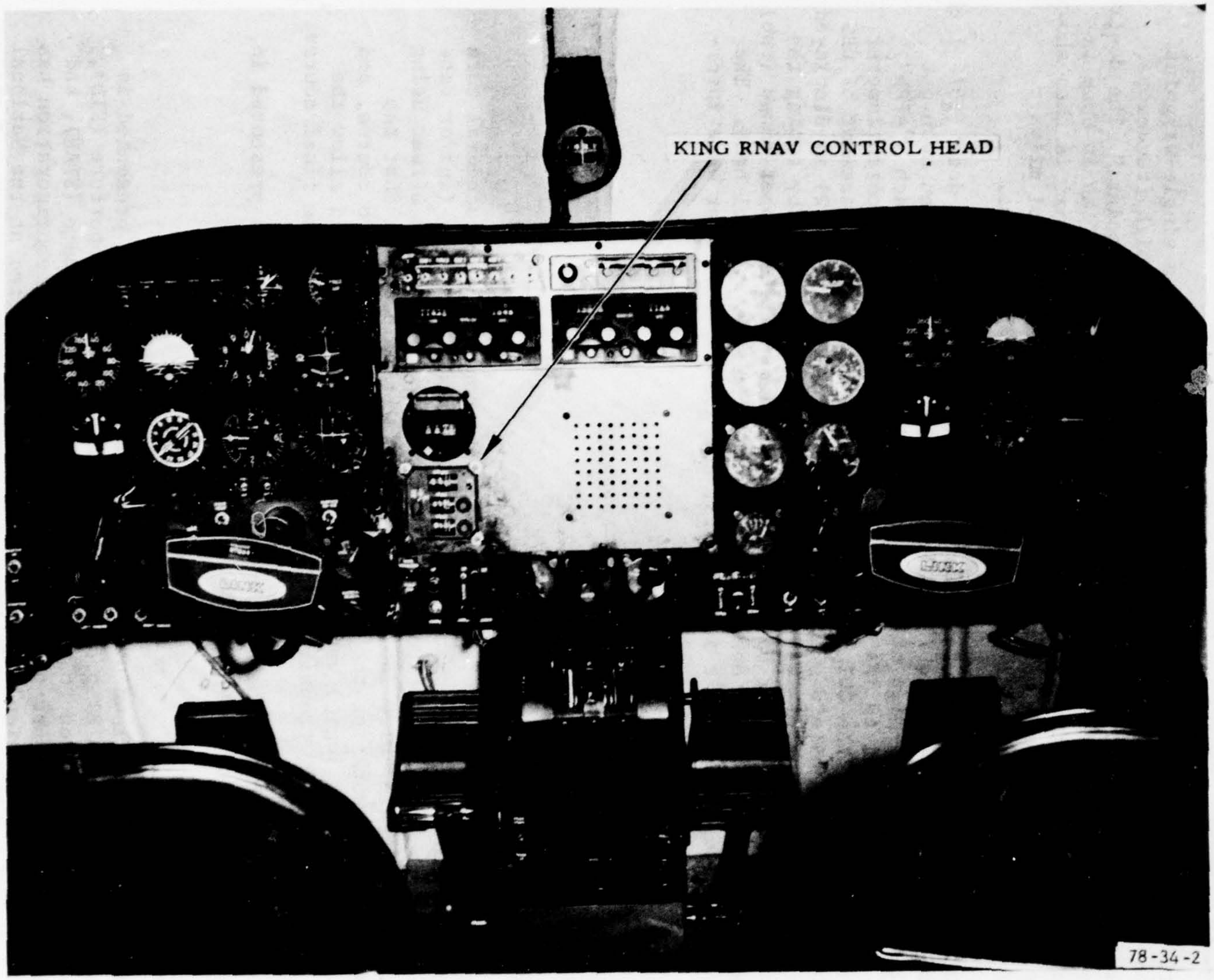

FIGURE 2. GAT-2A COCKPIT WITH KING KNC-610 RNAV UNIT

RNAV SYSTEM.

The Area Navigation (RNAV) system used in these tests was a single-waypoint station-oriented computer which, in effect, moved the very high frequency omnirange (VOR) position to a phantom location called a "waypoint." The desired course to the waypoint is set with the OBS control on the CDI, as is done in conventional VOR navigation. A corresponding course error signal is then shown on the CDI. The magnitude of the deviation is shown in nautical miles rather than degrees as is the case with conventional VOR systems.

The CDI needle used in these tests swings through a range of ±5 dots (±5/8 inch). When operating in the enroute ("RNAV") mode, the distance between each dot (1/8 inch) represents 1-mile of course deviation. In the approach ("APPR") mode, each dot is equal to 1/4 mile. A sine/cosine resolution potentiometer was incorporated into the CDI which permitted the accurate measurement of OBS settings made by the pilots. Aircraft Distance to Waypoint (DTW) is displayed directly on the RNAV unit. Waypoint selection is accomplished by tuning the No. 2 NAV unit to the proper VOR frequency and entering the proper range (rho) and bearing (theta) for the desired waypoint on the RNAV control head. The GAT-2A, RNAV computer, flight instruments, and XDS-530A computer were interfaced as shown in figure 3.

METHOD OF APPROACH

BACKGROUND.

The Phase II tests demonstrated that the pilots could use a procedural turn anticipation method based on an OBS set logic and CDI distance (and/or rate of movement) to anticipate turns while maintaining the desired offset using a noncentered needle CDI. The Phase II study also pointed out that the procedure did not work for the transition to the final approach course, and that a procedure (or logic) would have to be derived that would allow the pilots to successfully transition from the offset course to the final course.

The rationale for the CDI based turn anticipation technique is presented in the corresponding section of the Phase II data report.

ROUTE STRUCTURES.

All RNAV flights were flown using the route B1 configuration presented in figures 4 and 5. Route B1 provided a Standard Instrument Departure (SID), a route leg to transition to a Standard Terminal Arrival Route (STAR), and an RNAV approach procedure to runway 4/ACY. The route B1 configuration has been used in previous simulation and flight tests conducted at the National Aviation Facilities Experimental Center (NAFEC) and the University of Illinois for baseline studies. Figure 5 presents 2 nmi and 4 nmi left and right offset

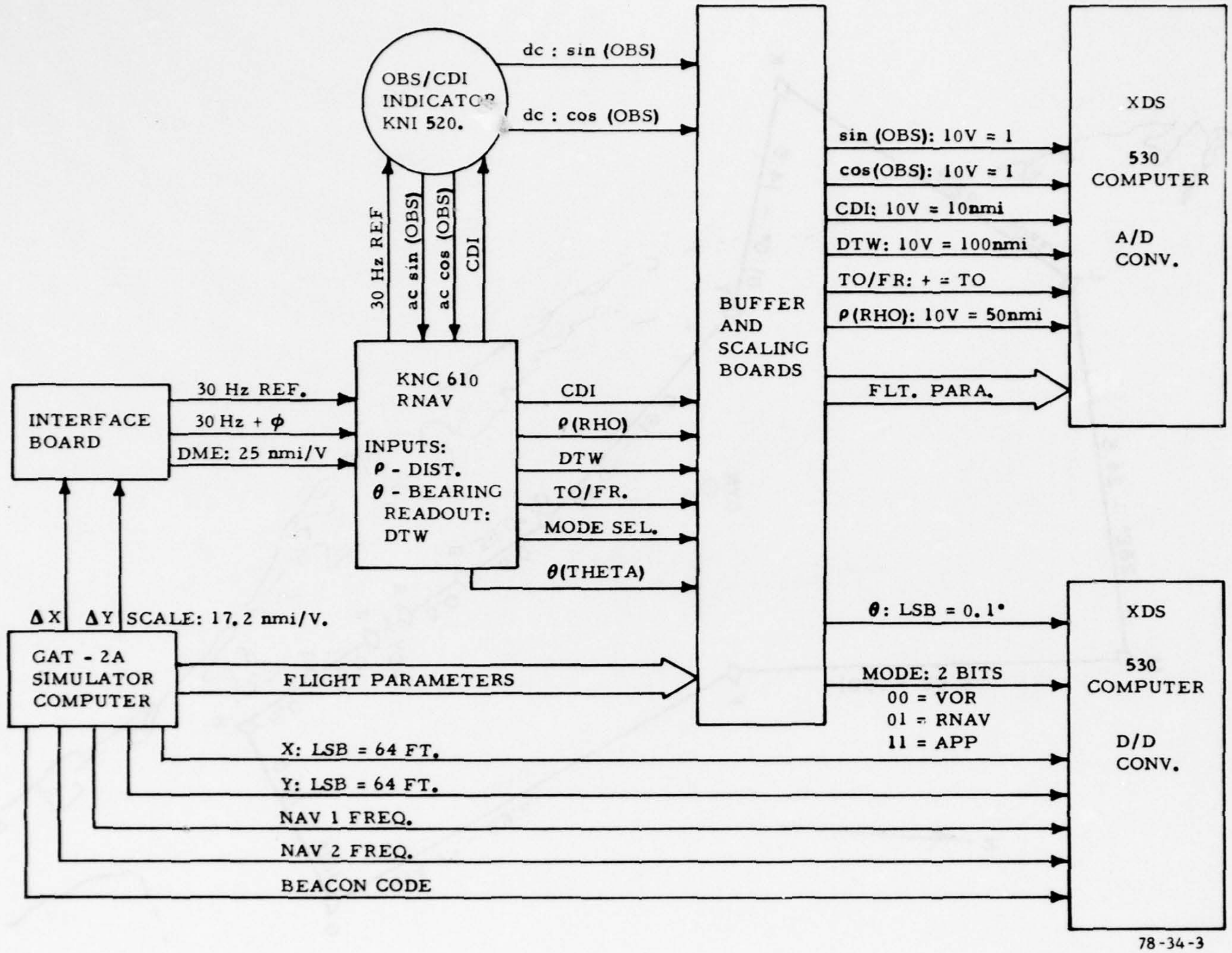

FIGURE 3. GAT-2/KING RNAV/XDS-530 COMPUTER INTERFACE DIAGRAM

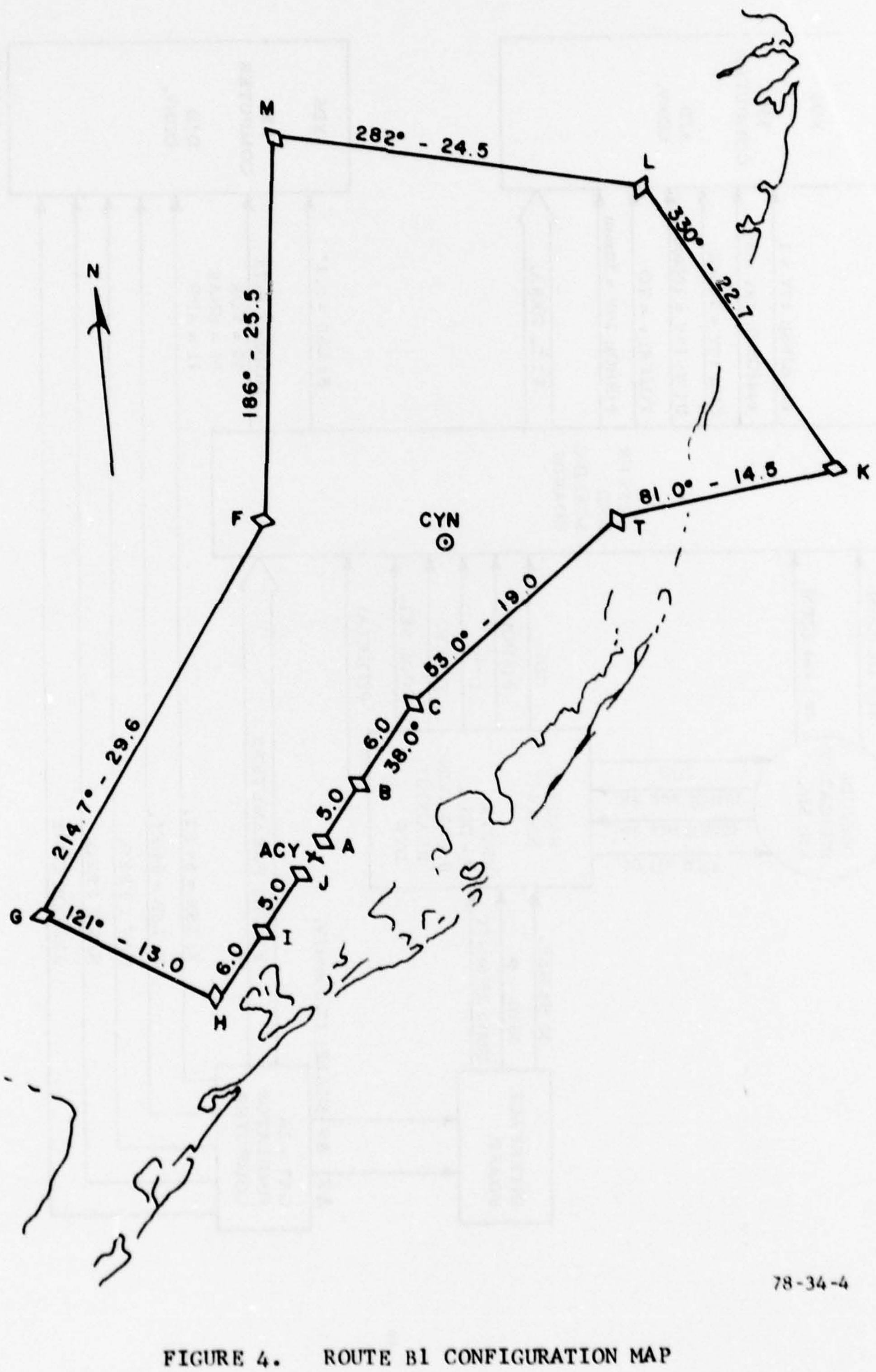

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FIGURE 4. ROUTE B1 CONFIGURATION MAP

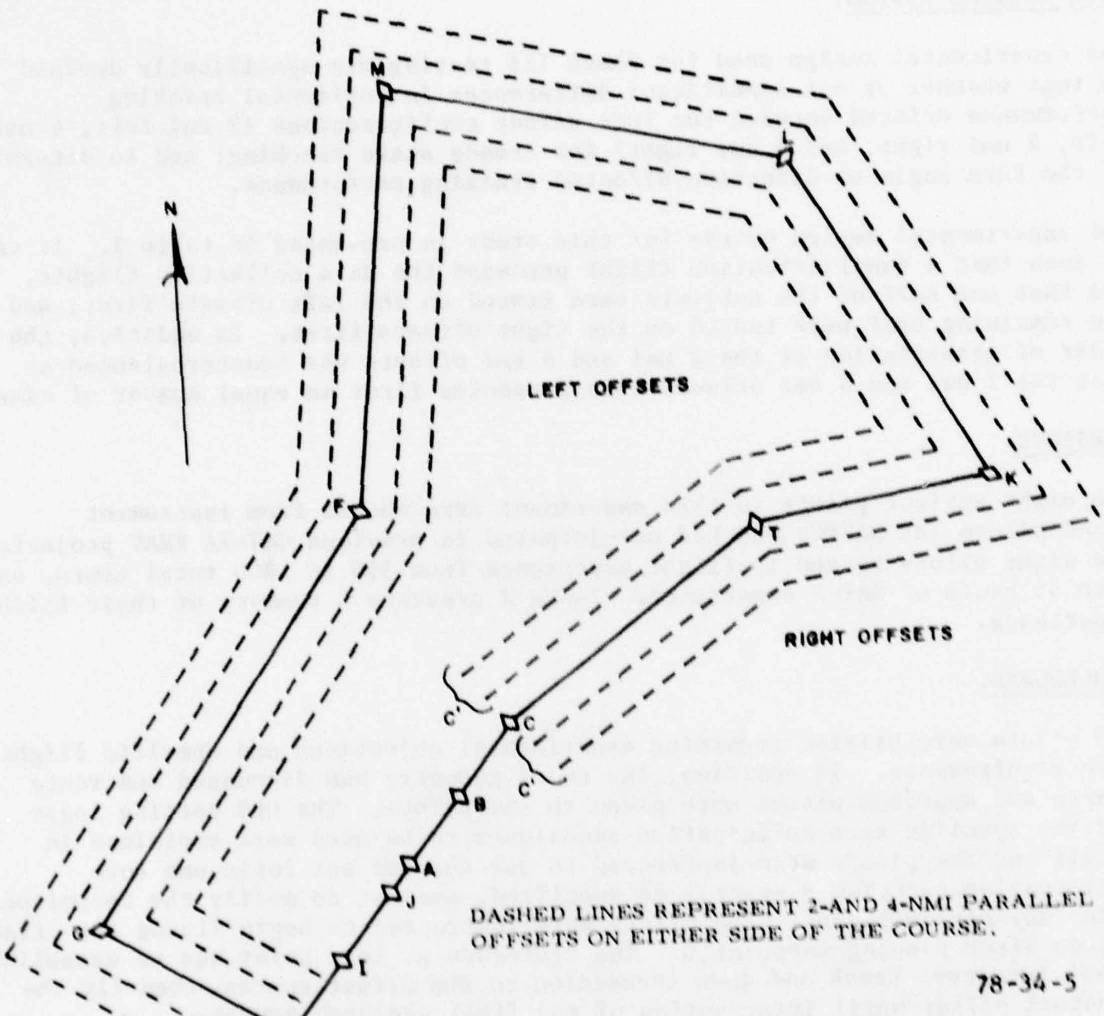

FIGURE 5. HORIZONTAL VIEW OF EXPERIMENTAL FLIGHT COURSE

configurations. The Phase III study was conducted using only the 2 and 4 nmi left and right offsets. The Phase II tests showed that 5 nmi offsets were not practical due to equipment limitations.

EXPERIMENTAL DESIGN.

The experimental design used for Phase III testing was specifically devised to test whether or not significant differences in horizontal tracking performance existed between the four offset configurations (2 nmi left, 4 nmi left, 2 nmi right, and 4 nmi right) for steady state tracking; and to determine if the turn angle or direction affected tracking performance.

The experimental design matrix for this study is presented in table 1. It can be seen that a familiarization flight preceded the data collection flights, and that one half of the subjects were tested on the left offsets first, and the remaining half were tested on the right offsets first. In addition, the order of presentation of the 2 nmi and 4 nmi offsets was counterbalanced so that the 2 nmi and 4 nmi offsets were presented first an equal number of times.

SUBJECTS.

The eight subject pilots in this experiment were chosen from instrument rated pilots (at NAFEC) who had participated in previous GAT-2A RNAV projects. The eight pilots ranged in flight experience from 350 to 1800 total hours, and 6 to 55 hours of GAT-2 experience. Table 2 presents a summary of their flight experience.

PROCEDURES.

The pilots were briefed regarding experimental objectives and specific flight task requirements. In addition, the route geometry was discussed and route charts and approach plates were given to the pilots. The OBS setting logic and the specific turn anticipation techniques to be used were explained in detail and the pilots were instructed to use the OBS set logic and turn anticipation techniques exactly as specified, and not to modify the techniques under any circumstances. The pilots were instructed to begin flying the offset course after passing waypoint C. The procedure at this point was to establish a 45° intercept track and then transition to the offset course, then fly the constant offset until interception of the final approach course.

During the offset flight, the pilot was expected to maintain 12,000 feet altitude and 160 knots indicated airspeed (i.e., approximately 195 knots TAS). The pilot was instructed to begin his descent at a point approximately 5 nmi after waypoint F and to descend and maintain 2,000 feet.

The charts defined the OBS setting, theta, rho, and frequency for each waypoint. After the pilots set the OBS, theta, rho, and frequency for a given waypoint, they were flying TO that waypoint. The TO flag was displayed on the CDI and DTW was decreasing. When they reached the wayline, the TO flag (within approximately +.5 nmi) disappeared and the DTW stopped decreasing (DTW did not reach zero, but approximated the offset distance).

TABLE 1. EXPERIMENTAL DESIGN CONFIGURATIONS

	Data Flights			Data Flights		
Subject No.	FAM*	4 nmi Left	2 nmi Left	FAM*	2 nmi Right	4 nmi Right
1	1	2	3	4	5	6
2	1	3	2	4	6	5
3	4	5	6	1	2	3
4	4	6	5	1	3	2
5	1	2	3	4	5	6
6	1	3	2	4	6	5
7	4	5	6	1	2	3
8	4	6	5	1	3	2

* FAM means familiarization flights.

The numbers under "Data Flights" represent the order in which each subject was tested.

TABLE 2. SUMMARY OF THE FLIGHT EXPERIENCE OF THE EIGHT SUBJECTS

Subject No.	License	Total Hrs.	Instrument Hrs.	GAT-2 Hrs.	RNAV Hrs.
1	Comm/Inst/Mult	1800+	310	45	10
2	Comm/Inst/Mult	960	90	50	20
3	Pvt/Inst	800+	150	6	5
4	Comm/Inst/Mult	1700+	300	55	35
5	Comm/Inst	980	65	45	5
6	Comm/Inst	360	60	6	5
7	Comm/Inst/Mult	560	94	6	5
8	Comm/Inst	500	80	10	6

The pilots were instructed to make an extra effort to fly with the CDI needle at the selected offset distance at all times. Furthermore, when starting the flight, the pilots were instructed to make sure that the RNAV Mode Selector switch was in RNAV Mode. The only time the pilots were allowed to use the APPROACH MODE was on final approach (H-J) waypoints. Each pilot was given familiarization flights before starting actual data collection (reference table 1). Specific charts were provided for the familiarization flights. The pilots were instructed that they could expect to encounter some mild turbulence with winds aloft during the flight. The pilots were advised as to wind and any weather conditions by the simulator operator, as well as other ATC clearances as required.

Upon completion of each familiarization flight, the subject pilot was immediately tested on the appropriate offset flights (reference table 1).

SPECIFIC TECHNIQUE FOR OFFSET TRACKING USING A CDI-BASED TURN ANTICIPATION TECHNIQUE.

The technique used in this Phase III effort consisted of three distinct required actions:

1. Implementation of the OBS set logic

2. Implementation of the turn logic.

3. Implementation of the final approach intercept logic

LOGIC FOR SETTING OBS DURING OFFSET TRACKING.

Course Change	Logic
1. Right offset/turn right	Twice offset value
2. Right offset/turn left	To/from indicator
3. Left offset/turn left	Twice offset value
4. Left offset/turn right	To/from indicator

In general, the rules for setting the OBS (for the next course) during offset tracking are as follows:

When on an offset, and the next course turn occurs after the waypoint, use the to/from indicator as a cue for setting the OBS to the next course (reference cases 2 and 4 above). (Note: When you cross the wayline (a line perpendicular to the course through the waypoint) the TO/FROM flag is neither TO nor FROM, but is "buried out of view.") At this point, set the OBS for the next course.

When on an offset, and the next course turn occurs prior to the waypoint, use a value that is twice the offset distance for setting the OBS to the next

course. For example, if a 4.0 nmi offset is being flown, the OBS will be set when distance to waypoint (DTW) reads 8.0 nmi (reference cases 1 and 3 above). Figure 6 represents the placard which was mounted directly above the RNAV Unit. This placard was to be used by the pilot to assist in applying these rules.

TURN LOGIC. Once the OBS has been set, the CDI needle will move from its present position and will either be pegged (at the extremes of the display) or will move toward the center of the display. The pilot will continue to maintain his present heading until the CDI needle approaches the desired offset distance. As the CDI needle approaches the desired offset distance, the pilot will have to use his judgment (based on the rate of CDI movement) to initiate his turn to the next course. As the aircraft is turning onto the next course, the pilot will monitor the CDI needle until it reaches the desired offset distance. Pilots are expected to turn at a rate not to exceed 3°/second (i.e., "standard rate turn"). The pilot should bear in mind that the faster the airspeed, the faster the CDI movement, and the more he will have to lead his turn.

TURN LOGIC FOR FINAL APPROACH TECHNIQUE. Left offset (or right offset) inside base leg (i.e., offset track is between the final approach fix and the initial approach fix for the final approach course).

Rules:

1. After completing turn at Golf, update to India waypoint.

2. After updating waypoint, set OBS to 038° final approach course.

3. Maintain current heading to intercept final approach course.

4. Use CDI as guide for turning onto final approach course.

Right offset (or left) outside base leg (i.e., offset track is beyond the initial approach fix).

Rules:

1. After completing turn at Golf, update to Hotel waypoint.

2. After updating waypoint, track offset CDI needle until twice the offset distance (DTW) to set OBS to the next course.

3. Use CDI as a guide for turning onto final approach course.

These rules for the OBS setting logic were derived by experimentation and actual testing, and appeared to offer a reliable means of establishing when the OBS should be set.

FOR OBS SET

OFFSET	TURN	LOGIC
RIGHT	RIGHT	DTW
	LEFT	T/F
LEFT	LEFT	DTW
	RIGHT	T/F

FIGURE 6. PLACARD USED TO ASSIST THE PILOT IN APPLYING THE OBS SET LOGIC

DATA COLLECTION PARAMETERS.

The data items extracted for this report include:

1. Crosstrack data (total system crosstrack) related to the transition from one segment to the next segment. This data was defined by envelopes ±2 nmi and ±4 nmi before and after a waypoint. These envelopes were sufficiently large to encompass all activities related to transitioning from one segment to the next segment.

2. Steady state total system crosstrack and flight technical error data. This data was defined as all data from 2 nmi after the waypoint to 2 nmi prior to the next waypoint.

3. Actual start turn distance (DTW, Distance to Wayline (DWYLIN), and time) used by the pilot. The heading time history data was used to establish this point.

4. Actual turn end distance (DTW, DWYLIN, and time) used by the pilot. The heading time history data was used to establish this point.

5. OBS setting (DTW, DWYLIN, and time).

RESULTS

DATA REDUCTION - OBS SET/START TURN DATA.

The first level of data reduction was directed toward extracting operational data concerning the pilot's performance of their RNAV related navigation tasks in order to comply with the assigned turn anticipation procedures.

Table 3 contains the OBS setting and start turn values for the following parameters:

1. DTW distance

2. WAYLINE distance

3. CDI displacement

The statistical values in this table are means. These values are presented as a function of turn angle (i.e., waypoint location and transition angle) and offset configuration, and are a summary of the operational data from all eight subjects. Tables 4 through 11 present the OBS setting times and and distances (including DTW, DWYLIN, and CDI displacement) and actual start turn times and distances (including DTW, distance to wayline (DWYLIN), and CDI displacement). Also included in these tables are the position of the to/from indicator and the magnitude of the turn angle. Each subject's data comprises one table. The left offsets are presented in part (a) and the right offsets are presented in part (b).

TABLE 3. SUMMARY OF OPERATIONAL DATA BASED ON THE OBS SET AND TURN LOGIC

				DTW Distance		Wayline Distance		CDI Displacement	
	Waypoint	Turn Angle	*OBS Logic	OBS Set	Start Turn	OBS Set	Start Turn	OBS Set	Start Turn
2.0 nmi Left Offset	T	28°	1	2.59	2.71	1.03	6.26	1.99	2.26
	K	111°	2	4.15	3.84	1.11	0.75	2.71	2.38
	L	48°	2	4.51	2.85	2.83	0.80	4.23	2.61
	M	96°	2	4.30	8.05	1.43	3.40	3.35	2.44
	F	29°	1	2.45	2.56	7.09	17.20	2.13	2.38
	G	93°	2	4.83	3.64	1.95	1.74	4.18	2.66
	H	84°	3	7.21	4.56	5.88	0.99	5.85	0.99
4.0 nmi Left Offset	T	28°	1	4.35	4.44	2.24	3.86	4.04	4.10
	K	111°	2	7.79	7.18	3.36	2.65	5.11	4.76
	L	48°	2	8.54	5.81	4.98	3.24	8.66	5.63
	M	96°	2	8.45	6.74	2.64	6.13	7.04	4.70
	F	29°	1	4.48	4.59	0.79	10.21	4.20	4.40
	G	93°	2	8.28	7.29	3.19	1.90	6.80	5.53
	H	84°	3	5.51	2.60	4.46	1.23	4.78	0.91
2.0 nmi Right Offset	T	28°	2	3.95	2.68	2.31	4.49	-3.43	-2.41
	K	111°	1	2.45	3.03	2.76	1.54	0.175	-0.93
	L	48°	1	2.33	2.96	0.60	20.26	-1.78	-2.64
	M	96°	1	2.45	2.71	2.00	1.18	-0.44	-1.15
	F	29°	2	4.24	2.81	2.63	12.26	-3.49	-2.50
	G	93°	1	3.98	2.69	1.96	2.59	-0.11	-4.66
	H	84°	3	4.23	2.41	3.00	0.99	3.20	0.88
4.0 nmi Right Offset	T	28°	2	7.80	5.39	5.06	4.74	-7.08	-4.84
	K	111°	1	4.60	6.29	5.90	2.04	1.01	-2.81
	L	48°	1	4.46	5.38	4.93	7.49	-3.51	-4.69
	M	96°	1	4.34	5.43	4.31	4.90	-0.30	-3.01
	F	29°	2	7.34	4.85	8.26	16.70	-6.54	-4.59
	G	93°	1	4.40	5.30	4.08	1.43	-0.11	-2.78
	H	84°	3	8.58	5.63	6.53	1.46	7.00	1.38

* 1 - Used To/From Logic
2 - Used Two Times Offset Distance
3 - Used Final Approach Logic

TABLE 4(a). OBS SET/START TURN DISTANCES FOR LEFT OFFSETS

Subject No. 1

				OBS Set					Turn Start					
	Waypoint	Turn Angle	*OBS Logic	Start Time	DTW Dist.	Wayline Dist.	CDI	To/ From/ Off	Start Time	DTW Dist.	Wayline Dist.	CDI	To/ From/ Off	Elapsed Time
2.0 nmi Left	T	28°	1	0795	2.0	0.8	1.6	Off	811	2.0	11.8	1.7	Off	16
	K	111°	2	1050	4.3	1.2	2.8	From	1066	3.9	0.5	2.3	From	16
	L	48°	2	1418	4.5	2.7	4.0	Off	1458	2.6	0.7	2.4	Off	40
	M	96°	2	1844	4.4	1.4	3.5	From	1861	3.7	0.4	2.6	From	17
	F	29°	1	2304	2.2	0.4	1.9	Off	2308	2.1	0.2	1.9	Off	4
	G	93°	2	2812	4.4	1.4	4.0	From	2824	4.0	0.9	3.4	From	12
	H	84°	3	3002	7.3	5.2	5.4	To	3152	4.5	0.6	0.6	To	50
4.0 nmi Left	T	28°	1	0793	4.0	1.3	3.7	To	830	4.6	9.0	4.5	Off	37
	K	111°	2	1005	8.7	1.7	6.0	From	1026	7.8	0.9	5.2	From	21
	L	48°	2	1272	8.5	4.9	8.6	Off	1366	5.4	0.3	5.0	From	94
	M	96°	2	1658	8.6	2.8	6.9	From	1707	6.5	0.3	4.5	From	49
	F	29°	1	2137	4.4	0.2	4.4	Off	2143	4.6	26.4	4.3	Off	6
	G	93°	2	2571	8.4	2.8	7.4	From	2611	7.0	0.9	5.4	From	40
	H	84°	3	2682	7.6	6.6	7.0	To	2840	3.6	1.1	1.1	To	158

TABLE 4(b). OBS SET/START TURN DISTANCE FOR RIGHT OFFSETS

Subject No. 1

				OBS Set					Turn Start					
	Waypoint	Turn Angle	*OBS Logic	Start Time	DTW Dist.	Wayline Dist.	CDI	To/ From/ Off	Start Time	DTW Dist.	Wayline Dist.	CDI	To/ From/ Off	Elapsed Time
2.0 nmi Right	T	28°	2	0741	4.5	3.0	-3.8	To	0813	2.5	16.3	-2.3	Off	72
	K	111°	1	1164	3.3	1.4	-0.7	To	1188	4.2	0.4	-1.5	To	24
	L	48°	1	1756	2.3	0.4	-1.9	To	1832	5.1	25.3	-5.0	Off	76
	M	96°	1	2285	2.6	1.8	-0.8	To	2297	2.8	1.2	-1.2	To	12
	F	29°	2	2751	4.4	2.7	-3.7	To	2796	2.5	0.3	-2.2	Off	45
	G	93°	1	3344	2.3	1.5	-0.4	To	3355	2.5	1.0	-0.8	To	11
	H	84°	3	3686	4.4	3.4	3.7	To	3757	2.3	1.1	1.3	To	71
4.0 nmi Right	T	28°	2	0655	8.5	6.0	-7.5	To	0737	4.6	1.7	-4.5	To	82
	K	111°	1	1083	4.5	5.5	0.8	To	1173	6.4	1.5	-3.0	To	90
	L	48°	1	1764	4.2	0.8	-3.5	To	1773	4.3	0.4	-3.8	To	9
	M	96°	1	2251	4.4	4.2	-0.2	To	2304	5.4	1.2	-3.2	To	53
	F	29°	2	2716	8.5	6.0	-7.4	To	2820	4.5	0.1	-4.5	Off	104
	G	93°	1	3336	4.2	3.7	-0.3	To	3381	4.6	1.4	-2.6	To	45
	H	84°	3	3633	8.9	7.0	7.4	To	3827	5.1	1.0	1.2	To	94

*1 - Used To/From Logic
2 - Used Two Times Offset Distance Logic
3 - Used Final Approach Logic

TABLE 5(a). OBS SET/START TURN DISTANCE FOR LEFT OFFSETS

Subject No. 2

				OBS Set					Turn Start					
	Waypoint	Turn Angle	*OBS Logic	Start Time	DTW Dist.	Wayline Dist.	CDI	To/From/Off	Start Time	DTW Dist.	Wayline Dist.	CDI	To/From/Off	Elapsed Time
2.0 nmi Left	T	28°	1	0794	2.3	0.1	2.1	Off	0797	2.3	11.8	2.1	Off	3
	K	111°	2	1066	2.8	0.4	1.4	From	1073	2.7	0.7	1.1	From	7
	L	48°	2	1411	5.2	3.5	4.9	To	1470	2.6	0.4	2.3	Off	59
	M	96°	2	1818	5.3	2.3	4.3	From	1860	3.3	23.5	2.1	From	42
	F	29°	1	2328	2.7	27.1	2.7	Off	2335	3.0	26.7	2.8	From	7
	G	93°	2	2726	6.8	3.8	6.6	Off	2800	3.5	0.2	2.4	From	74
	H	84°	3	2952	7.6	5.9	6.2	To	3086	4.3	0.7	0.7	To	134
4.0 nmi Left	T	28°	1	0776	4.4	1.7	3.9	To	0787	4.3	1.2	4.1	To	11
	K	111°	2	0990	8.9	2.3	6.8	From	1009	8.3	1.5	6.0	From	19
	L	48°	2	1250	8.6	5.2	8.9	Off	1325	5.9	1.5	6.0	Off	75
	M	96°	2	1628	8.7	3.1	7.3	From	1660	7.1	1.4	5.7	From	32
	F	29°	1	2052	4.5	0.9	4.1	From	2060	4.5	0.4	4.3	To	8
	G	93°	2	2473	7.6	1.9	6.2	From	2485	7.1	1.1	5.7	From	12
	H	84°	3	2607	4.6	3.6	4.1	To	2654	3.0	1.6	2.0	To	47

TABLE 5(b). OBS SET/START TURN DISTANCE FOR RIGHT OFFSETS

Subject No. 2

				OBS Set					Turn Start					
	Waypoint	Turn Angle	*OBS Logic	Start Time	DTW Dist.	Wayline Dist.	CDI	To/From/Off	Start Time	DTW Dist.	Wayline Dist.	CDI	To/From/Off	Elapsed Time
2.0 nmi Right	T	28°	2	0732	4.8	3.5	-3.7	To	0790	2.6	0.8	-2.3	Off	58
	K	111°	1	1119	2.3	3.3	0.5	To	1143	2.5	2.3	-0.5	To	24
	L	48°	1	1658	2.4	1.0	-1.6	To	1669	2.7	0.4	-1.9	To	11
	M	96°	1	2143	2.4	2.4	-0.1	To	2160	2.7	1.5	-0.9	To	17
	F	29°	2	2609	4.4	3.0	-3.4	To	2646	2.9	0.9	-2.5	To	37
	G	93°	1	3180	2.6	1.2	-0.7	To	3193	2.9	0.5	-1.4	To	13
	H	84°	3	3485	5.1	4.0	4.4	To	3570	2.5	1.1	1.4	To	85
4.0 nmi Right	T	28°	2	0713	7.6	4.8	-7.7	To	0794	5.1	1.1	-5.3	Off	81
	K	111°	1	1119	4.7	6.8	1.9	To	1228	5.9	2.3	-2.7	To	109
	L	48°	1	1834	4.5	1.9	-3.2	To	1847	4.6	1.2	-3.7	To	13
	M	96°	1	2367	4.0	4.3	-0.6	To	2419	5.3	1.6	-3.3	To	52
	F	29°	2	2845	8.4	5.5	-7.7	To	2946	4.7	32.9	-4.8	Off	101
	G	93°	1	3440	4.4	4.3	0.1	To	3494	5.2	1.3	-2.9	To	54
	H	84°	3	3753	8.1	6.2	6.3	To	3880	4.6	1.3	1.3	To	127

* 1 - Used To/From Logic
2 - Used Two Times Offset Distance Logic
3 - Used Final Approach Logic

TABLE 6(a). OBS SET/START TURN DISTANCE FOR LEFT OFFSETS

Subject No. 3

				OBS Set					Turn Start					
	Waypoint	Turn Angle	*OBS Logic	Start Time	DTW Dist.	Wayline Dist.	CDI	To/ From/ Off	Start Time	DTW Dist.	Wayline Dist.	CDI	To/ From Off	Elapsed Time
2.0 nmi Left	T	28°	1	0749	2.0	1.2	1.1	To	0781	2.1	11.4	1.7	Off	32
	K	111°	2	1033	3.8	0.7	2.5	From	1042	3.4	0.4	2.2	From	9
	L	48°	2	1409	4.3	2.8	4.0	To	1453	2.4	0.7	2.2	Off	44
	M	96°	2	1850	3.8	1.2	3.0	From	1871	3.0	0.1	1.7	From	21
	F	29°	1	2325	2.6	0.1	2.2	Off	2345	3.2	27.4	3.0	Off	20
	G	93°	2	2716	4.9	2.2	4.2	From	2738	3.6	0.7	2.7	From	22
	H	84°	3	2866	7.7	5.4	5.5	To	2972	4.9	1.1	1.0	To	106
4.0 nmi Left	T	28°	1	0747	3.9	2.1	3.0	To	0776	3.6	0.8	3.3	Off	29
	K	111°	2	0964	7.7	1.6	5.1	From	0974	7.3	1.2	4.9	From	10
	L	48°	2	1228	8.4	4.9	8.5	Off	1285	5.8	2.0	5.9	Off	57
	M	96°	2	1619	7.5	1.4	7.6	Off	1678	5.5	21.8	2.3	From	59
	F	29°	1	2060	4.2	1.0	3.7	To	2082	4.5	26.2	4.3	Off	22
	G	93°	2	2437	8.3	2.5	7.0	From	2446	7.7	1.9	6.6	From	9
	H	84	3	2648	3.4	1.8	1.7	To	2676	2.8	0.9	0.9	To	28

TABLE 6(b). OBS SET/START TURN DISTANCE FOR RIGHT OFFSETS

Subject No. 3

				OBS Set					Turn Start					
	Waypoint	Turn Angle	*OBS Logic	Start Time	DTW Dist.	Wayline Dist.	CDI	To/ From/ Off	Start Time	DTW Dist.	Wayline Dist.	CDI	To/ From Off	Elapsed Time
2.0 nmi Right	T	28°	2	0756	2.8	0.9	-2.7	Off	0767	2.7	0.4	-2.5	Off	11
	K	111°	1	1087	2.3	3.3	0.5	To	1096	2.3	2.9	0.3	To	9
	L	48°	1	1633	2.3	0.6	-1.9	To	1664	3.1	26.8	-2.9	Off	31
	M	96°	1	2121	2.2	2.3	-0.1	To	2137	2.5	1.4	-0.9	To	16
	F	29°	2	2535	4.2	2.6	-3.5	To	2543	3.9	2.1	-3.3	To	8
	G	93°	1	3079	2.7	2.0	-0.2	To	3082	2.7	1.8	-0.2	To	3
	H	84°	3	3324	4.3	3.0	2.5	To	3392	2.5	0.0	0.3	To	68
4.0 nmi Right	T	28°	2	0695	8.0	5.4	-7.4	To	0904	7.3	15.1	-4.8	From	209
	K	111°	1	1165	5.1	4.2	-0.8	To	1222	6.4	1.8	-3.1	To	57
	L	48°	1	1837	4.5	0.8	-3.9	To	1847	4.7	0.3	-4.2	To	10
	M	96°	1	2361	4.4	3.8	-0.9	To	2398	5.4	1.8	-2.8	To	37
	F	29°	2	2856	7.1	3.9	-6.6	To	2915	5.3	0.6	-5.1	Off	59
	G	93°	1	3354	4.4	4.5	0.5	To	3393	5.1	1.9	-2.1	To	39
	H	84°	3	3626	8.6	6.5	6.9	To	3802	5.1	0.7	0.9	To	176

* 1 - Used To/From Logic
2 - Used Two Times Offset Distance Logic
3 - Used Final Approach Logic

TABLE 7(a). OBS SET/START TURN DISTANCE FOR LEFT OFFSETS

Subject No. 4

				OBS Set					Turn Start					
	Waypoint	Turn Angle	*OBS Logic	Start Time	DTW Dist.	Wayline Dist.	CDI	To/ From/ Off	Start Time	DTW Dist.	Wayline Dist.	CDI	To/ From/ Off	Elapsed Time
2.0 nmi Left	T	28°	1	0832	2.0	1.1	1.5	Off	0844	2.0	0.5	1.7	Off	12
	K	111°	2	1104	4.9	1.7	3.4	From	1106	4.9	1.6	3.6	From	2
	L	48°	2	1468	4.9	3.1	4.9	Off	1510	3.6	1.2	3.4	From	42
	M	96°	2	1924	4.6	1.2	3.7	From	1937	4.2	0.5	3.1	From	13
	F	29°	1	2420	2.9	27.6	2.9	Off	2427	3.1	27.2	3.0	From	7
	G	93°	2	2844	4.9	1.8	4.0	From	2856	4.1	1.1	3.4	From	12
	H	84°	3	2973	8.5	6.2	6.5	To	3084	6.2	1.7	1.8	To	111
4.0 nmi Left	T	28°	1	0858	4.6	0.8	4.4	Off	0870	4.8	0.3	4.6	Off	12
	K	111°	2	1091	7.6	0.3	4.5	From	1091	7.6	0.3	4.8	To	-
	L	48°	2	1329	8.7	5.1	9.0	Off	1408	6.4	1.2	6.1	From	79
	M	96°	2	1699	8.9	3.0	7.2	From	1748	6.7	21.5	4.5	From	49
	F	29°	1	2130	4.4	1.2	4.2	Off	2142	4.5	0.6	4.5	Off	12
	G	93°	2	2580	8.8	2.9	7.3	From	2607	7.6	1.3	5.8	From	27
	H	84°	3	2688	6.4	5.6	5.8	To	2816	2.5	0.7	0.8	To	128

TABLE 7(b). OBS SET/START TURN DISTANCE FOR RIGHT OFFSETS

Subject No. 4

				OBS Set					Turn Start					
	Waypoint	Turn Angle	*OBS Logic	Start Time	DTW Dist.	Wayline Dist.	CDI	To/ From/ Off	Start Time	DTW Dist.	Wayline Dist.	CDI	To/ From/ Off	Elapsed Time
2.0 nmi Right	T	28°	2	0763	3.4	1.4	-3.3	Off	0811	2.7	16.0	-2.3	Off	48
	K	111°	1	1113	2.3	2.7	0.4	To	1157	3.3	0.8	-1.5	To	44
	L	48°	1	1690	2.2	0.5	-1.7	To	1707	2.5	27.4	-2.4	To	17
	M	96°	1	2177	2.6	2.0	-0.4	To	2193	2.8	1.1	-1.1	To	16
	F	29°	2	2652	4.2	2.6	-3.6	To	2702	2.6	31.2	-2.4	Off	50
	G	93°	1	3234	3.0	0.3	-2.0	To	3234	3.0	0.3	-2.8	Off	-
	H	84°	3	3558	4.3	3.3	3.4	To	3627	2.6	0.6	0.7	To	69
4.0 nmi Right	T	28°	2	0824	8.4	5.9	-7.3	To	0975	5.9	16.0	-4.5	From	151
	K	111°	1	1226	4.8	5.3	0.8	To	1323	7.3	1.2	-3.0	To	97
	L	48°	1	1984	4.7	30.7	-4.4	To	1988	4.7	30.6	-4.5	To	4
	M	96°	1	2484	4.2	4.8	0.3	To	2544	5.4	1.6	-2.7	To	60
	F	29°	2	2993	8.3	5.8	-7.2	To	3059	5.0	2.3	-4.9	To	66
	G	93°	1	3619	4.2	4.1	0.1	To	3674	5.4	1.3	-2.8	To	55
	H	84°	3	3952	8.5	6.7	7.1	To	4164	10.5	0.8	1.0	To	212

* 1 - Used To/From Logic
2 - Used Two Times Offset Distance Logic
3 - Used Final Approach Logic

TABLE 8(a). OBS SET/START TURN DISTANCE FOR LEFT OFFSETS

Subject No. 5

				OBS Set					Turn Start					
	Waypoint	Turn Angle	*OBS Logic	Start Time	DTW Dist.	Wayline Dist.	CDI	To/ From/ Off	Start Time	DTW Dist.	Wayline Dist.	CDI	To/ From/ Off	Elapsed Time
2.0 nmi Left	T	28°	1	0780	2.4	0.9	2.0	To	0787	2.4	0.6	2.0	To	7
	K	111°	2	1061	4.4	1.2	3.1	From	1074	4.1	0.7	2.7	From	13
	L	48°	2	1431	4.2	2.4	4.2	Off	1459	3.0	1.1	3.0	Off	28
	M	96°	2	1851	4.3	1.4	3.3	From	1865	3.6	0.6	2.7	From	14
	F	29°	1	2289	2.4	0.6	2.0	To	2308	2.5	27.9	2.5	Off	19
	G	93°	2	2795	4.4	1.3	3.7	From	2819	3.6	0.1	2.5	From	24
	H	84°	3	2940	8.9	7.2	7.5	To	3131	4.7	0.9	0.9	To	191
4.0 nmi Left	T	28°	1	0888	4.1	0.3	4.2	Off	0902	4.5	9.0	3.9	From	14
	K	111°	2	1116	7.1	0.9	4.5	From	1134	6.8	0.1	3.8	From	18
	L	48°	2	1363	8.4	4.9	8.6	Off	1452	5.5	0.6	5.2	Off	89
	M	96°	2	1752	8.7	2.6	6.8	From	1787	7.1	0.8	5.0	From	35
	F	29°	1	2192	4.7	0.7	4.4	To	2201	4.8	0.2	4.6	To	9
	G	93°	2	2661	8.6	2.5	7.0	From	2715	6.7	0.2	4.8	From	54
	H	84°	3	2816	6.7	5.9	6.0	To	2981	2.7	0.3	0.2	To	165

TABLE 8(b). OBS SET/START TURN DISTANCE FOR RIGHT OFFSETS

Subject No. 5

				OBS Set					Turn Start					
	Waypoint	Turn Angle	*OBS Logic	Start Time	DTW Dist.	Wayline Dist.	CDI	To/ From/ Off	Start Time	DTW Dist.	Wayline Dist.	CDI	To/ From/ Off	Elapsed Time
2.0 nmi Right	T	28°	2	0736	4.2	2.9	-3.5	To	0766	2.8	1.5	-2.7	To	30
	K	111°	1	1130	2.4	2.9	0.5	To	1181	3.3	0.8	-1.5	To	51
	L	48°	1	1723	2.3	0.5	-1.8	To	1741	2.7	27.3	-2.4	To	18
	M	96°	1	2216	2.4	1.6	-0.9	To	2225	2.6	1.1	-1.2	To	9
	F	29°	2	2660	4.2	2.9	-3.4	To	2710	2.2	0.0	-2.1	Off	50
	G	93°	1	3245	2.1	1.4	-0.6	To	3263	2.5	0.6	-1.3	To	18
	H	84°	3	3667	2.7	0.9	1.0	To	3676	2.6	0.6	0.8	To	9
4.0 nmi Right	T	28°	2	0676	8.4	6.1	-7.3	To	0789	4.7	0.9	-4.8	Off	113
	K	111°	1	1127	4.3	6.3	1.4	To	1234	5.8	1.9	-3.3	To	114
	L	48°	1	1825	4.3	1.4	-3.3	To	2009	11.0	25.5	-10.2	Off	84
	M	96°	1	2530	4.4	4.1	-0.3	To	2589	6.1	1.0	-3.5	To	59
	F	29°	2	3027	8.1	5.3	-7.1	To	3121	4.6	32.8	-4.6	Off	94
	G	93°	1	3643	4.5	3.4	-0.4	To	3700	5.7	0.6	-3.3	To	57
	H	84°	3	4032	8.5	6.6	7.0	To	4232	4.8	0.7	0.9	To	200

* 1 - Used To/From Logic
2 - Used Two Times Offset Distance Logic
3 - Used Final Approach Logic

TABLE 9(a). OBS SET/START TURN DISTANCE FOR LEFT OFFSETS

Subject No. 6

				OBS Set					Turn Start					
	Waypoint	Turn Angle	*OBS Logic	Start Time	DTW Dist.	Wayline Dist.	CDI	To/From/Off	Start Time	DTW Dist.	Wayline Dist.	CDI	To/From/Off	Elapsed Time
2.0 nmi Left	T	28°	1	0808	1.4	0.8	1.0	Off	0831	2.2	11.5	1.7	Off	23
	K	111°	2	1078	4.1	1.1	2.2	From	1091	3.5	0.5	1.6	From	13
	L	48°	2	1458	4.2	2.5	3.7	Off	1496	2.7	0.6	2.2	From	38
	M	96°	2	1877	3.8	1.4	2.6	From	1892	3.2	0.6	1.9	From	15
	F	29°	1	2333	2.1	0.2	1.5	To	2347	2.1	27.6	1.7	Off	14
	G	93°	2	2757	4.3	1.9	3.3	From	2777	3.4	10.3	1.9	From	20
	H	84°	3	2893	8.0	5.7	6.3	To	3026	5.2	1.1	1.2	To	33
4.0 nmi Left	T	28°	1	0890	5.7	8.8	5.5	Off	0881	5.5	9.1	4.4	From	-
	K	111°	2	1147	5.5	16.1	1.9	From	1145	5.5	16.1	3.9	To	-
	L	48°	2	1421	8.9	5.1	8.4	To	1537	5.9	16.6	4.7	From	116
	M	96°	2	1792	8.5	3.3	6.9	From	1827	6.8	1.4	4.9	From	35
	F	29°	1	2229	4.4	0.3	3.9	To	2240	4.4	26.4	4.1	To	11
	G	93°	2	2635	8.0	2.9	6.4	From	2639	7.8	2.7	6.2	From	4
	H	84°	3	2778	4.9	3.6	4.6	Off	2856	1.2	3.9	0.6	Off	78

TABLE 9(b). OBS SET/START TURN DISTANCE FOR RIGHT OFFSETS

Subject No. 6

				OBS Set					Turn Start					
	Waypoint	Turn Angle	*OBS Logic	Start Time	DTW Dist.	Wayline Dist.	CDI	To/From/Off	Start Time	DTW Dist.	Wayline Dist.	CDI	To/From/Off	Elapsed Time
2.0 nmi Right	T	28°	2	0778	4.0	2.6	-3.5	To	0822	2.2	0.4	-1.9	Off	44
	K	111°	1	1156	2.1	2.8	0.1	To	1189	3.0	1.3	-1.2	To	33
	L	48°	1	1725	2.3	0.7	-1.8	To	1731	2.4	0.4	-2.0	To	6
	M	96°	1	2211	2.4	2.0	-0.4	To	2229	2.8	1.0	-1.4	To	18
	F	29°	2	2687	4.1	2.5	-3.3	To	2735	2.6	31.3	-2.3	Off	48
	G	93°	1	3212	2.3	2.1	-0.5	To	3244	3.1	14.3	-2.2	To	32
	H	84°	3	3569	4.4	3.0	3.6	To	3656	2.4	1.6	0.8	To	87
4.0 nmi Right	T	28°	2	0701	8.5	6.2	-7.4	To	0826	4.8	0.3	-4.8	Off	125
	K	111°	1	1153	4.2	5.7	0.5	To	1257	6.8	1.4	-3.7	To	104
	L	48°	1	1863	4.5	1.4	-3.5	To	1879	4.5	0.6	-4.1	To	16
	M	96°	1	2373	4.3	4.6	-0.2	To	2437	5.4	27.6	-4.0	To	64
	F	29°	2	2967	4.3	32.4	-3.9	Off	2997	4.3	31.0	-3.1	From	30
	G	93°	1	3445	4.2	4.6	-0.3	To	3509	5.8	1.2	-3.7	To	64
	H	84°	3	3811	8.7	6.3	7.1	To	3961	4.4	3.2	0.9	To	150

* 1 - Used To/From Logic
2 - Used Two Times Offset Distance Logic
3 - Used Final Approach Logic

TABLE 10(a). OBS SET/START TURN DISTANCE FOR LEFT OFFSETS

Subject No. 7

				OBS Set					Turn Start					
	Waypoint	Turn Angle	*OBS Logic	Start Time	DTW Dist.	Wayline Dist.	CDI	To/ From/ Off	Start Time	DTW Dist.	Wayline Dist.	CDI	To/ From/ Off	Elapsed Time
2.0 nmi Left	T	28°	1	0726	4.1	4.1	3.6	From	0750	3.3	3.0	2.5	From	24
	K	111°	2	1240	4.4	1.4	3.2	From	1262	3.8	0.5	2.3	From	22
	L	48°	2	1623	4.5	3.0	4.0	Off	1655	3.2	1.4	2.9	To	32
	M	96°	2	2040	4.3	1.7	3.4	From	2050	3.9	1.2	2.9	From	10
	F	29°	1	2480	2.3	0.4	1.6	Off	2488	2.2	0.0	1.8	To	8
	G	93°	2	2914	4.5	1.6	3.6	From	2930	3.7	0.6	2.7	From	16
	H	84°	3	3098	4.8	6.8	4.7	To	3219	5.0	0.9	0.8	To	121
4.0 nmi Left	T	28°	1	0780	4.0	1.4	4.0	To	0797	4.0	0.6	4.0	To	17
	K	111°	2	0985	8.1	1.8	5.5	From	1010	7.0	0.8	4.7	From	25
	L	48°	2	1267	8.4	4.7	8.6	To	1321	5.8	2.1	6.1	Off	54
	M	96°	2	1651	8.2	2.2	6.5	From	1676	7.1	0.9	5.3	From	25
	F	29°	1	2077	4.7	0.6	4.4	To	2078	4.7	0.6	4.4	To	1
	G	93°	2	2487	8.5	7.5	6.0	From	2505	8.3	7.1	5.1	From	18
	H	84°	3	2594	4.9	4.0	4.4	From	2720	1.9	0.2	0.6	To	126

TABLE 10(b). OBS SET/START TURN DISTANCE FOR RIGHT OFFSETS

Subject No. 7

				OBS Set					Turn Start					
	Waypoint	Turn Angle	*OBS Logic	Start Time	DTW Dist.	Wayline Dist.	CDI	To/ From/ Off	Start Time	DTW Dist.	Wayline Dist.	CDI	To/ From/ Off	Elapsed Time
2.0 nmi Right	T	28°	2	0769	3.3	0.9	-3.0	Off	0781	3.0	0.3	-2.8	Off	12
	K	111°	2	1138	2.4	3.1	0.4	To	1174	2.9	1.7	-0.9	To	36
	L	48°	1	1754	2.4	0.5	-1.7	To	1771	2.7	27.2	-2.4	To	17
	M	96°	1	2253	2.6	1.8	-0.6	To	2264	2.8	1.2	-1.1	To	11
	F	29°	2	2738	3.7	1.8	-3.3	To	2749	3.4	1.2	-3.1	To	11
	G	93°	1	3264	2.4	1.5	-0.5	To	3270	2.5	1.1	-0.7	To	6
	H	84°	3	3561	4.6	3.3	3.6	To	3630	2.6	1.4	1.8	To	69
4.0 nmi Right	T	28°	2	0687	7.9	5.5	-7.1	To	0774	5.4	1.6	-5.4	Off	87
	K	111°	1	1105	4.3	6.6	1.5	To	1165	5.0	4.0	-1.1	To	60
	L	48°	1	1777	4.7	0.9	-3.7	To	1784	4.7	0.6	-3.9	To	7
	M	96°	1	2299	4.5	4.9	-0.4	To	2338	5.0	1.9	-2.3	To	39
	F	29°	2	2777	8.4	5.4	-7.1	To	2846	5.5	1.6	-5.4	Off	69
	G	93°	1	3347	4.4	4.0	-0.1	To	3386	4.8	1.9	-2.1	To	39
	H	84°	3	3641	8.7	6.8	7.3	To	3755	5.7	3.1	3.5	To	114

* 1 - Used To/From Logic
2 - Used Two Times Offset Distance Logic
3 - Used Final Approach Logic

TABLE 11(a). OBS SET/START TURN DISTANCE FOR LEFT OFFSETS

Subject No. 8

				OBS Set					Turn Start					
	Waypoint	Turn Angle	*OBS Logic	Start Time	DTW Dist.	Wayline Dist.	CDI	To/From/Off	Start Time	DTW Dist.	Wayline Dist.	CDI	To/From/Off	Elapsed Time
2.0 nmi Left	T	28°	1	0757	2.3	1.3	1.6	To	0773	2.1	0.6	1.8	Off	16
	K	111°	2	1031	4.5	1.2	3.1	From	1033	4.4	1.1	3.2	From	2
	L	48°	2	1393	4.3	2.6	4.1	Off	1440	2.7	0.3	2.5	From	47
	M	96°	2	1835	3.9	0.8	2.8	From	1844	3.5	0.3	2.5	From	9
	F	29°	1	2292	2.4	0.3	2.2	To	2287	2.3	0.6	2.3	Off	-
	G	93°	2	2754	4.4	1.6	4.0	From	2788	3.2	0.0	2.3	From	34
	H	84°	3	2996	4.9	4.6	4.7	Off	3132	1.7	0.9	0.9	From	136
4.0 nmi Left	T	28°	1	0782	4.1	1.5	3.6	To	0795	4.2	0.9	4.0	To	13
	K	111°	2	0988	8.7	2.2	6.6	From	1032	7.1	0.3	4.8	From	44
	L	48°	2	1275	8.6	5.0	8.7	Off	1343	5.8	1.6	6.0	Off	68
	M	96°	2	1654	8.5	2.7	7.1	From	1687	7.1	0.9	5.4	From	33
	F	29°	1	2066	4.5	1.4	4.5	To	2075	4.7	0.9	4.7	To	9
	G	93°	2	2452	8.0	2.5	7.1	From	2490	6.1	0.0	4.6	From	38
	H	84°	3	2646	5.6	4.6	4.6	To	2769	3.1	1.1	1.1	To	123

TABLE 11(b). OBS SET/START TURN DISTANCE FOR RIGHT OFFSETS

Subject No. 8

				OBS Set					Turn Start					
	Waypoint	Turn Angle	*OBS Logic	Start Time	DTW Dist.	Wayline Dist.	CDI	To/From/Off	Start Time	DTW Dist.	Wayline Dist.	CDI	To/From/Off	Elapsed Time
2.0 nmi Right	T	28°	2	0713	4.6	3.3	-3.9	To	0783	2.9	0.2	-2.5	Off	70
	K	111°	1	1136	2.5	2.6	-0.3	To	1147	2.7	2.1	-0.6	To	11
	L	48°	1	1706	2.4	0.6	-1.8	To	1716	2.5	27.3	-2.1	To	10
	M	96°	1	2203	2.4	2.1	-0.3	To	2225	2.7	0.9	-1.4	To	22
	F	29°	2	2683	4.7	2.9	-3.7	To	2744	2.4	31.1	-2.1	Off	61
	G	93°	1	3175	4.4	5.7	4.0	To	3259	2.3	1.1	-0.9	To	84
	H	84°	3	3610	4.0	3.1	3.4	To	3751	1.8	1.5	-0.1	To	141
4.0 nmi Right	T	28°	2	0782	5.1	0.6	-4.9	Off	0767	5.3	1.2	-4.6	Off	-
	K	111°	1	1084	4.9	6.8	2.0	To	1194	6.7	2.2	-2.6	To	10
	L	48°	1	1790	4.3	1.5	-2.6	To	1805	4.5	0.7	-3.1	To	15
	M	96°	1	2298	4.5	4.7	-0.1	To	2339	5.4	2.5	-2.3	To	41
	F	29°	2	2840	5.6	1.8	-5.3	Off	2889	4.9	32.3	-4.3	From	47
	G	93°	1	3361	4.9	4.0	-0.5	To	3403	5.8	1.8	-2.7	To	42
	H	84°	3	3712	8.6	6.1	6.9	To	3893	4.8	0.9	1.3	To	182

* 1 - Used To/From Logic
2 - Used Two Times Offset Distance Logic
3 - Used Final Approach Logic

From table 3, it can be seen that for the most part, the pilot did apply the rules established for the OBS setting logic. For the left offsets, four of the six turns required that the OBS be set at a distance that was two times the offset value. From these data, it appears that the pilot did not have a problem with using the required rule. The other two turns (at T and at F) required that the OBS be set upon movement of the to/from indicator. From these data, it can be seen that the required action resulted in the OBS being set at a DTW distance equivalent to the offset distance, which in turn required the pilot to initiate the transition to the next segment almost immediately.

From table 3, it is evident that for the right offsets, four of the six turns required that the OBS be set upon movement of the to/from indicator. From these data, it appears that the pilot did not have a problem with using the required rule. The other two turns (at T and at F) required that the OBS be set at a distance that was two times the offset value. The data indicates that the required action was implemented at the desired DTW distance.

The turn at waypoint "H" was not considered in the above explanations since the logic for the transition to the final approach course was different than the other two turn logics. The data in table 3, however, indicate that the pilots followed the required logic.

Even though the pilots adhered to the OBS setting logic for both the left and right offsets, the turn logic appears to have caused considerable variability in times and distances for the right offsets. The left offset CDI displacement values are consistent with that which was expected and the pilots did perform as expected and initiated the transition to the next course at the appropriate point. An explanation concerning the expected CDI needle movement is included in the appropriate section of the Phase II data report.

TOTAL SYSTEM CROSSTRACK ERROR (TSCT) - TURN DATA.

The second level of data reduction was directed toward measurement of crosstrack error during the transitions at waypoints T, K, L, M, F, and G in order to determine if the turn logic resulted in turns that did not exceed a two Root Mean Squared (RMS) value of ±1.5 nmi. Table 12 presents the mean sigma and RMS statistics based on the time series data from 2 nmi prior to the waypoint to 2 nmi after the waypoint. Table 13 presents the mean sigma and RMS statistics based on the time series data from 4 nmi prior to the waypoint to 4 nmi after the waypoint. From the tables 12 and 13 it can be seen that the turn data did not exceed a 2 RMS value of ±2 nmi. Further, the RMS variability was greater for the left offsets than for the right offsets, and that the 4 nmi left offset transition at way point L exceeded a 2 RMS value of ±1.5 nmi. The difference in variability between the left and right offsets may be attributable to the right CDI needle bias (reference table 14).

The total system crosstrack error for the turn data at waypoint H (which used a centered CDI needle), did not exceed a 2 RMS value of ±1.5 nmi.

TABLE 12. TURN DATA - TSCT ERROR (±2.0 nmi WINDOW)

	2 nmi Left Offset			4 nmi Left Offset			2 nmi Right Offset			4 nmi Right Offset			Summary			
Segment	$\bar{x}$	σ	RMS	$\bar{x}$	σ	RMS	$\bar{x}$	σ	RMS	$\bar{x}$	σ	RMS	$\bar{x}$	σ	RMS	2 RMS
T 28°	.451	.185	.550	.512	.190	.586	.306	.159	.388	.539	.223	.631	.452	.189	.539	1.077
K 111°	.299	.282	.448	.395	.427	.619	-.223	.402	.552	-.385	.363	.609	.021	.368	.557	1.114
L 48°	-.331	.172	.497	-.959	.234	.992	-.196	.282	.458	-.307	.178	.425	-.449	.217	.593	1.186
M 96°	.232	.351	.437	.039	.388	.463	-.191	.230	.322	-.460	.211	.521	-.095	.296	.435	.870
F 29°	-.350	.201	.441	-.158	.070	.212	-.272	.107	.322	-.269	.160	.365	-.262	.135	.335	.670
G 93°	.390	.285	.527	-.087	.328	.675	.159	.227	.338	-.159	.199	.318	.076	.260	.464	.928
Mean RMS			.483			.591			.396			.478				
2 RMS			.967			1.182			.793			.956				
H 84°	.277	.407	.504	-.130	.364	.652	-.086	.250	.418	.169	.299	.474	-.027	.330	.512	1.024

TABLE 13. TURN DATA - TSCT ERROR (±4.0 nmi WINDOW)

	2 nmi Left Offset			4 nmi Left Offset			2 nmi Right Offset			4 nmi Right Offset			Summary			
Segment	$\bar{x}$	σ	RMS	$\bar{x}$	σ	RMS	$\bar{x}$	σ	RMS	$\bar{x}$	σ	RMS	$\bar{x}$	σ	RMS	2 RMS
T 28°	.516	.203	.589	.594	.258	.664	.349	.168	.416	.404	.296	.550	.466	.231	.555	1.110
K 111°	.242	.405	.507	.299	.536	.636	.183	.435	.531	-.282	.459	.583	.019	.459	.564	1.128
L 48°	-.326	.215	.489	-.899	.246	.935	-.285	.305	.515	-.361	.214	.459	-.468	.245	.600	1.200
M 96°	.087	.363	.412	.003	.513	.583	-.276	.250	.381	-.474	.204	.529	-.165	.332	.476	.952
F 29°	-.333	.231	.453	-.129	.123	.248	-.290	.114	.328	-.348	.219	.446	-.275	.172	.369	.738
G 93°	.435	.270	.570	.041	.364	.660	.177	.215	.339	-.068	.213	.320	.146	.266	.472	.944
Mean RMS			.503			.621			.418			.481				
2 RMS			1.007			1.242			.837			.962				
H 84°	.369	.418	.564	.068	.390	.536	.012	.263	.350	.053	.303	.413	.093	.343	.466	.932

TABLE 14. CALIBRATION VALUES FOR THE CDI INSTRUMENT USED IN THIS STUDY

	Left					Center			Right		
Dots	-5	-4	-3	-2	-1	0	1	2	3	4	5
Volts*	-5.25	-4.15	-3.06	-2.00	-1.03	.010	1.00	1.99	3.10	4.30	5.65

*Voltage is equivalent to nautical mile displacement.

STEADY STATE DATA - TOTAL SYSTEM CROSSTRACK ERROR AND FLIGHT TECHNICAL ERROR (FTE).

Table 15 presents the mean, sigma, and RMS statistics for the offset steady state tracking data (i.e., Total System Crosstrack Error (TSCT) for all segments between waypoints C' and H (or H'). The same statistics were also computed for all tracking data between waypoint H (or H') and waypoint J; however, this data was based on using the RNAV approach mode (i.e., 1 Dot=1/4 nmi). The statistics were computed based on the time series data from 2 nmi after the waypoint to 2 nmi prior to the waypoint. An evaluation of the turn and steady state tracking data indicated that the ± 2 nmi turn data window was sufficient to encompass all of the turn data and that the steady state data was not affected by the turn data.

From table 15 it is evident that in three segments, tracking performance resulted that exceeded a 2 RMS value of ± 1.5 nmi. Two of these occurred during the 4 nmi left offset, and the third occurred during the 2 nmi left offset. Only one of these three exceeded a 2 RMS value of ± 2 nmi.

In general, the left offsets were more variable (in terms of TSCT error) than the right offsets. Once again, this may have been due to the CDI needle bias. These data indicate that the tracking proficiency (TSCT error), except for three offset cases, do fall within either a 2 RMS value of ± 1.5 nmi, or a 2 RMS value of ± 2 nmi for the steady state data. These data however, are influenced by one pilot's initial flights which were the 2 nmi and 4 nmi left offsets. This pilot was a minimum time Instrument Flight Regulations (IFR) pilot (approximately 60 hours), and he had the lowest overall time (approximately 360 hours). This particular subject improved his performance over subsequent flights, and by his last flight (i.e., sixth - including two familiarization flights) it was difficult to distinguish his performance from that of the other seven pilots.

Figure 7 presents RMS TSCT error for the steady state data and the turn data (both $\pm$ 2 nmi and ± 4 nmi error window). From figure 7, it can be seen that the difference in variability between the left and right offsets exists for both the steady state and the turn data; furthermore, it is evident that there is no difference in the magnitude of the steady state and turn data. This similiarity in both data sets would suggest that the turn logic works and does not result in errors larger than those incurred for the steady state tracking.

TABLE 15. MEAN, SIGMA AND RMS STEADY STATE TRACKING DATA (TSCT)

	2 nmi Left Offset			4 nmi Left Offset			2 nmi Right Offset			4 nmi Right Offset			Summary	
Segment	$\bar{x}$	σ	RMS	$\bar{x}$	σ	RMS	$\bar{x}$	σ	RMS	$\bar{x}$	σ	RMS	RMS	2 RMS
C* - T	.543	.385	.711	.883	.583	1.062	.244	.361	.451	-.084	.535	.607	.707	1.414
T - K	.605	.169	.646	.739	.196	.784	.317	.182	.395	.284	.209	.361	.546	1.092
K - L	-.328	.163	.398	-.606	.193	.639	-.582	.222	.628	-.509	.219	.567	.558	1.116
L - M	-.334	.222	.420	-.529	.238	.594	-.486	.295	.588	-.519	.307	.668	.567	1.134
M - F	-.072	.233	.309	-.059	.341	.466	-.361	.203	.427	-.338	.234	.442	.411	.822
F - G	-.067	.312	.409	-.037	.297	.398	-.119	.220	.311	-.275	.271	.438	.389	.778
G - H	.774	.162	.835	.471	.159	.587	.121	.197	.287	.025	.143	.366	.518	1.036
Mean RMS			.533			.647			.441			.493		
2 RMS			1.066			1.294			.882			.986		
H - J*	.136	.081	.174	.043	.076	.160	.189	.124	.232	.152	.095	.183	.187	.374

*The data for these segments was based on using the RNAV Approach Mode (1 DOT = 1/4 nmi) and was center needle tracking.

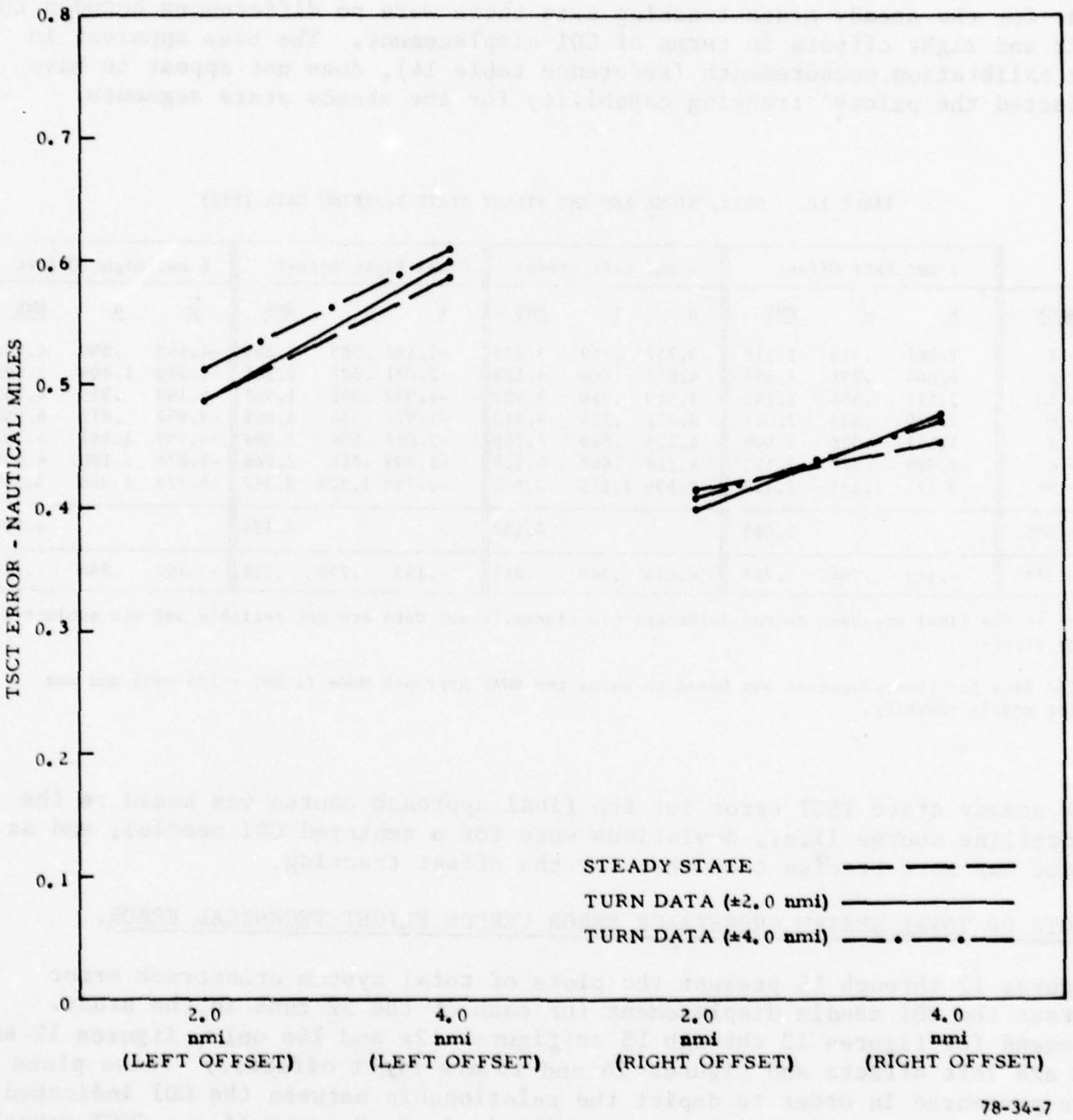

FIGURE 7. RMS TSCT ERROR-TURN DATA (±2 NMI, ±4 NMI) AND STEADY STATE DATA

Figures 8 through 11 present the composite plots for the 2 nmi left, 4 nmi left, 2 nmi right, and 4 nmi right offsets.

Table 16 presents the mean, sigma and RMS statistics for the offset steady state CDI displacement (FTE) for all segments between waypoints C' and H (or H'). The same statistics were also computed for all tracking data between waypoint H (or H') and waypoint J; however, this data was based on using the RNAV approach mode (i.e. 1 Dot=1/4 nmi). The statistics were computed on the same basis as the TSCT data. From table 16, it can be seen that for the steady state tracking data there were no differences between the left and right offsets in terms of CDI displacement. The bias apparent in the calibration measurements (reference table 14), does not appear to have affected the pilots' tracking capability for the steady state segments.

TABLE 16. MEAN, SIGMA AND RMS STEADY STATE TRACKING DATA (FTE)

	2 nmi Left Offset			4 nmi Left Offset			2 nmi Right Offset			4 nmi Right Offset		
Segment	$\bar{x}$	σ	RMS	$\bar{x}$	σ	RMS	$\bar{x}$	σ	RMS	$\bar{x}$	σ	RMS
C* - T	1.867	.413	1.918	3.757	.769	3.839	-2.167	.583	2.245	-4.145	.860	4.236
T - K	1.864	.291	1.889	4.051	.606	4.128	-2.021	.827	2.208	-3.540	1.804	3.996
K - L	2.111	.354	2.145	4.519	.310	4.532	-1.932	.352	1.967	-4.193	.555	4.235
L - M	2.020	.535	2.044	4.451	.734	4.513	-1.975	.334	2.006	-3.952	.871	4.058
M - F	1.967	.378	2.009	4.124	.849	4.289	-2.018	.504	2.084	-4.089	1.443	4.351
F - G	2.094	.318	2.123	4.218	.642	4.329	-1.899	.716	2.066	-3.878	1.100	4.032
G - H*	2.121	1.121	2.423	2.599	1.875	3.505	-1.753	1.526	2.362	-4.176	1.348	4.399
Mean RMS			2.085			4.162			2.134			4.186
H - J**	-.113	.204	.244	-.034	.240	.264	-.143	.259	.311	- .102	.265	.286

* Due to the final approach course intercept procedures, these data are not reliable and are subject to large errors.

** The data for these segments was based on using the RNAV Approach Mode (1 DOT = 1/4 nmi) and was center needle tracking.

The steady state TSCT error for the final approach course was based on the centerline course (i.e., deviations were for a centered CDI needle), and as such, was more precise than that for the offset tracking.

PLOTS OF TOTAL SYSTEM CROSSTRACK ERROR VERSUS FLIGHT TECHNICAL ERROR.

Figures 12 through 15 present the plots of total system crosstrack error versus the CDI needle displacement for each of the 32 runs in the study. (Legend for figures 12 through 15 on figures 12a and 14a only, figures 12 and 13 are left offsets and figures 14 and 15 are right offsets.) These plots are presented in order to depict the relationship between the CDI indicated position and where the aircraft actually is in X, Y space (i.e., TSCT error). From these plots, it can be seen where the OBS was set, and where the bearing and distance values were set into the RNAV unit, and their effect on CDI displacement.

SUMMARY.

This section presents a summary of the major findings in this study as well as a discussion of problems inherent in the use of the offset turn anticipation logic. The data obtained from this Phase III effort, turned out to be nearly equivalent to the Phase II effort, and as such provides a good data base for further evaluation of general aviation RNAV systems.

In this study, the steady state TSCT error for offset tracking was the same magnitude as the offset turn data TSCT error. The reason for this is that the turns were made using a set of logic that required the pilot to pay close attention to the CDI needle and the pilots did a reasonable job of transitioning between segments with minimum TSCT error.

TABLE 17. SUMMARY OF THE OVERALL 2 RMS ($\pm$2.0 NMI WINDOW) TSCT ERRORS

	2 nmi Left Offset	4 nmi Left Offset	2 nmi Right Offset	4 nmi Right Offset
Steady State Data	1.066	1.294	.882	.986
Turn Data	.966	1.182	.792	.956

The to/from logic, however, does allow the pilot to "get into trouble" during the transition at the shallow angle turns (T, L, and F) in that upon setting the OBS, the CDI needle has little or no movement which results in a lack of time to observe CDI needle motion.

Figure 16 depicts the geometry at waypoint L, and is presented in order to explain a problem with the to/from logic for right or left offsets. The rules for the to/from logic state that the OBS should be set at a point where the to/from flag is "buried out of view." The CDI distance at this point (assuming that the aircraft is on course) will be approximately the distance of the offset (i.e., 2 or 4 nmi in this study). For a right offset the pilot must immediately initiate the turn to the next segment (within approximately 8 to 16 seconds after setting the OBS) because the CDI needle either moves very little or not at all and, therefore, the pilot cannot use needle movement as a cue for initiating the turn. The problems stated above contributed to two blunders at waypoint L.

The first occurred during a 2 nmi right offset and resulted in a TSCT error of 2.74 nmi right of course. The pilot commented that the CDI needle did not change when he set the OBS and he became confused. In this case, the CDI needle eventually drifted out to 5 dots left; however, the pilot did not attempt to recenter the needle for approximately 76 seconds. For the second case (a 4 nmi right offset) the pilot also expected the needle to show some movement and became confused. The problem in this case was compounded by the fact that the needle pegged to the left. The pilot stayed on course, waiting for the needle to move, and eventually committed a blunder of 5.73 nmi right of course. The pilot had to be directed to return to course.

In a similar case, another pilot flying a 2 nmi left offset incurred an error of 1.45 nmi left of course while transitioning at waypoint F (29° transition). This occurred as a result of the pilot waiting to observe the CDI needle movement. The pilot initiated the turn when the CDI read 3 nmi right.

These three cases point out a weakness in the to/from OBS set logic and subsequent turn logic that could result in blunders when used under actual IFR conditions. The problem would become even more critical at higher speeds and the logic of OBS set/turn would not be useable for shallow angle turns, and would require the implementation of a DTW based logic which would take into account the turn angle and speed of the aircraft.

The problem with the shallow angle turns is further demonstrated by the data in table 18.

TABLE 18. ELAPSED TIME BETWEEN OBS SET AND START TURN FOR SHALLOW ANGLE TURNS AT WAYPOINTS L AND F

Waypoint	Left Offset		Right Offset	
	2 nmi	4 nmi	2 nmi	4 nmi
L (48°)	41 seconds (2x)	67 seconds (2x)	16 seconds (T/f)	11 seconds (T/f)
F (29°)	11 seconds (T/f)	8 seconds (T/f)	39 seconds (2x)	71 seconds (2x)

An alternative solution would be to train the pilots to react to the shallow angle turns as quickly as possible, and to start the turn almost immediately after setting the OBS to the next course.

A potential problem area exists which is directly attributable to the noncentered CDI needle. The pilot's workload is increased with the noncentered CDI needle because he has to fly away from the needle and in other cases he has to fly toward the needle. Under high workload conditions, this could cause confusion which might cause the pilots to fly in the wrong direction. In fact, in this study there were three instances of this wrong needle sensing. One occurred at waypoint T which resulted in an error of 2 nmi right of course.

Another occurred at waypoint G and resulted in the pilot flying 4 nmi off course, but parallel to the intended offset course between waypoints G and H. A third case occurred at waypoint F where the pilot sensed the needle wrongly; however, he realized his error and returned to the offset course. In this case the pilot corrected to the needle instead of away from the needle.

The final approach logic, as implemented during the G-H segment, appears to cause considerable difficulty for the left offsets. In this study, the right offsets were flown using CDI guidance for approximately three quarters of the distance between G and H. For the left offsets, the pilot, in order to implement the required logic, has to reset the OBS immediately upon completing the transition at G (refer to the pilot procedures section) and was required to maintain a heading for the length of the segment without CDI guidance. The data in table 15 shows the results of these different required actions. From table 15, it can be seen that the RMS variability was approximately two times greater for the left offsets than for the right offsets (0.711 nmi versus 0.323 nmi). These results indicate that maintaining a heading, while tracking a course, is less accurate than using a noncentered CDI needle for tracking guidance.

In summary, the final approach intercept logic used in this study works and did provide transition from the right offsets to the final approach course. However, the logic did not work as well for the left offsets.

A problem related to the initial acquisition of an offset course resulted in a greater amount of crosstrack variability on the first offset segment (the segment along which the offset was initially intercepted) than on other offset segments. With a single waypoint analog RNAV system, using a noncentered CDI needle, the pilot had to establish a 45° intercept track and then transition to the offset course in order to establish the required offset; the pilot had to fly away from the CDI needle and transition to the offset. In the process, overshoots and undershoots occurred and stabilization of the flight along the offset course was derogated.

Based on the results of this study, it is apparent that steady state offset data, using a noncentered CDI needle, can be expected to exceed a 2 RMS value of ± 1.5 nmi for the 4 nmi offsets; and that turns made while maintaining offsets (using a CDI movement based turn anticipation logic), can be expected to exceed a 2 RMS value of ± 1.5 nmi for the 4-nmi offsets. Moreover, none of the steady state or turn data exceeded a 2 RMS of ± 2 nmi.

When flying a 4-nmi offset around turns (using the two times the offset value logic for setting the OBS), the CDI needle will be pegged at the extremes of the display. Under such conditions the pilot must maintain a heading until he senses movement of the CDI needle toward the desired offset value. During this time it is possible for the pilot to drift off course and the CDI needle will not provide the necessary guidance and could result in a blunder.

From this study, it was also determined that the placard provided in the cockpit was essential in order for the pilots to implement the turn logic. Only one of the eight pilots indicated that he could remember the logic, and would not use the placard.

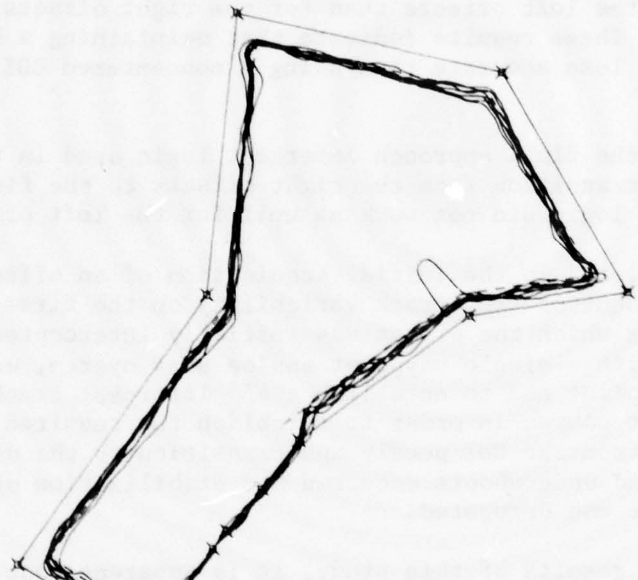

FIGURE 8. COMPOSITE PLOT OF 2 NMI LEFT OFFSETS

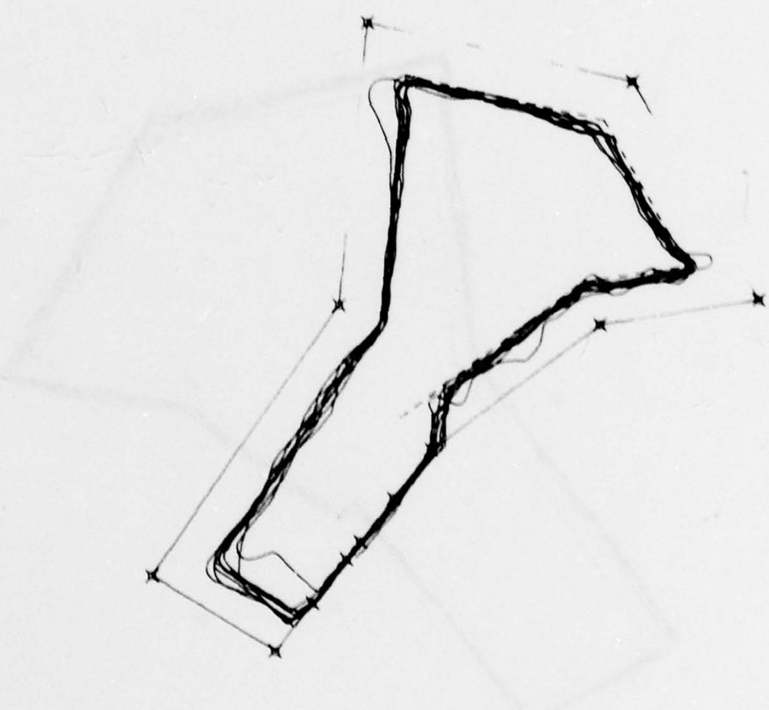

FIGURE 9. COMPOSITE PLOT OF 4 NMI LEFT OFFSETS

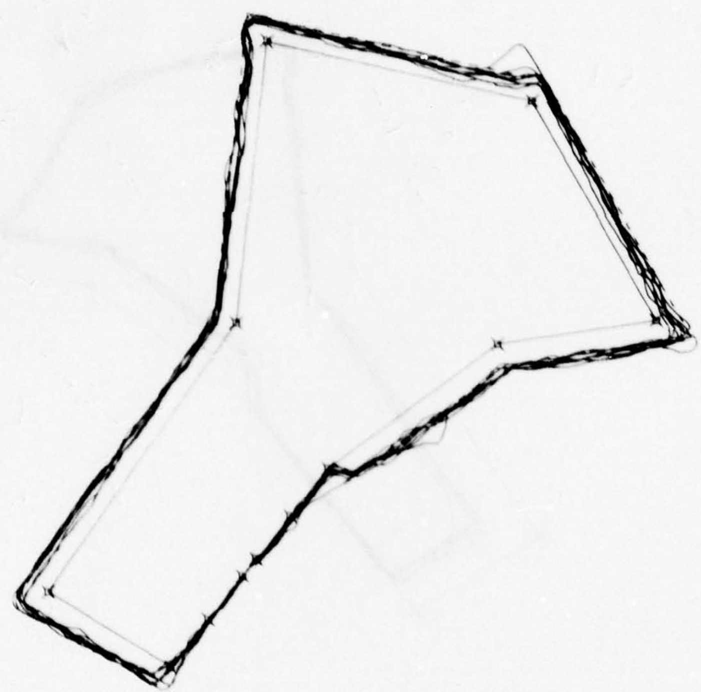

FIGURE 10. COMPOSITE PLOT OF 2 NMI RIGHT OFFSETS

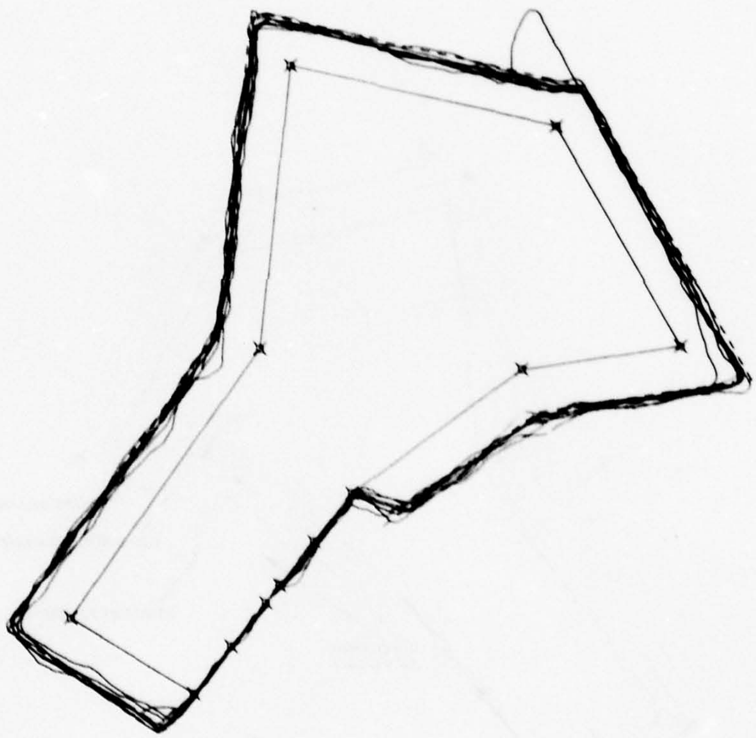

FIGURE 11. COMPOSITE PLOT OF 4 NMI RIGHT OFFSETS

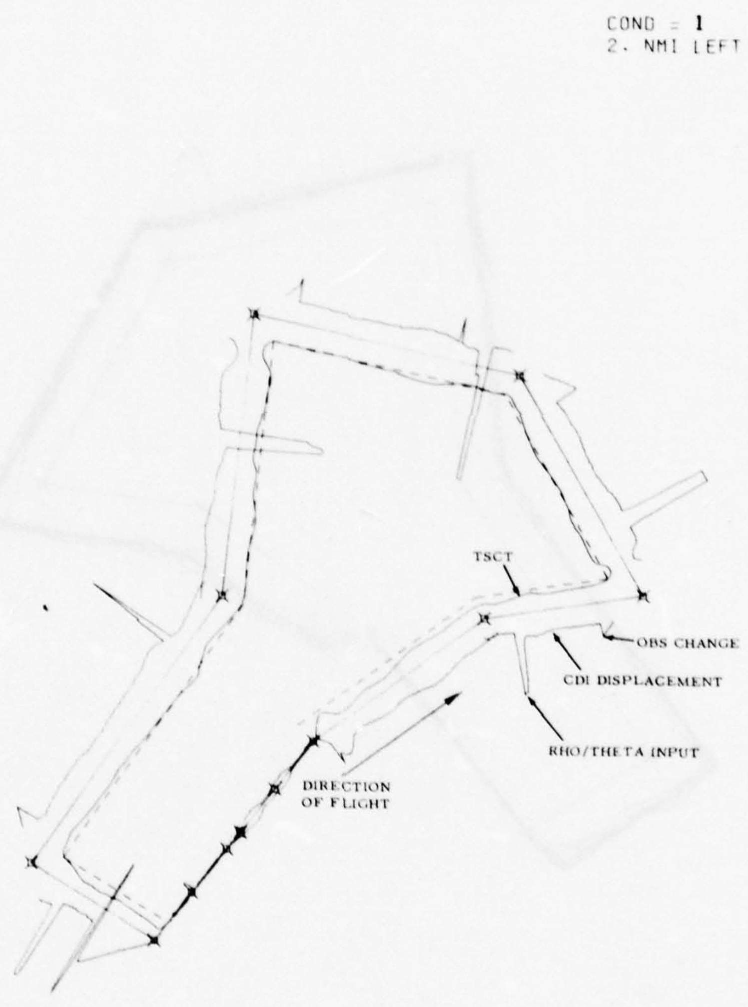

FIGURE 12a. INDIVIDUAL PLOTS OF 2 NMI LEFT OFFSET (TSCT VS. FTE)

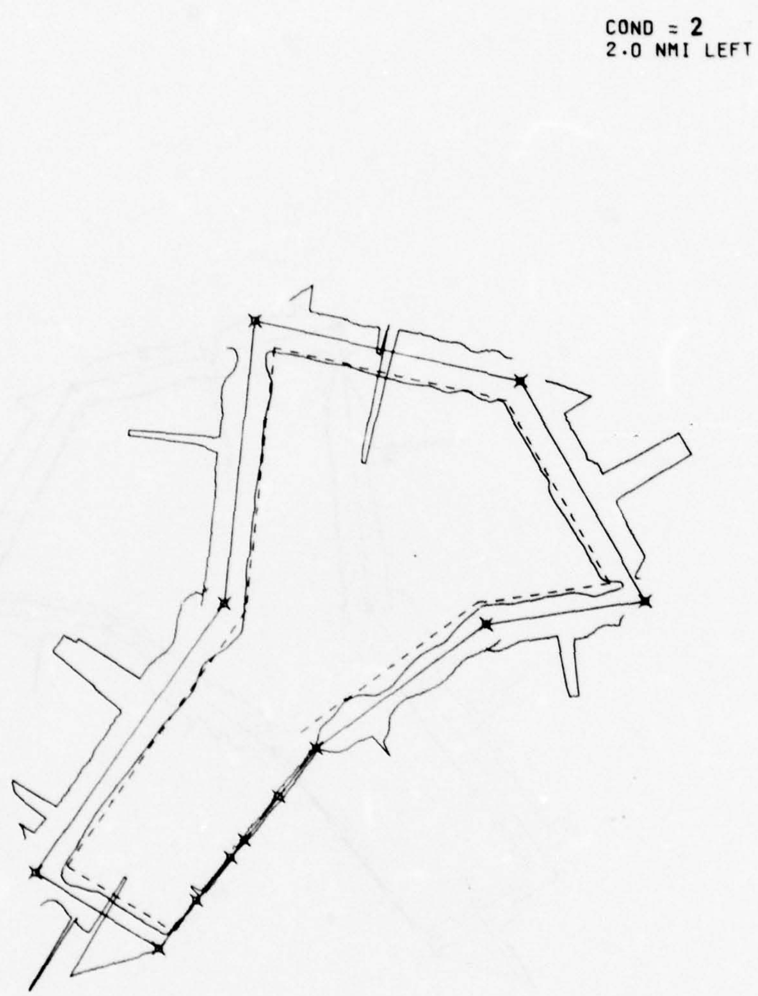

FIGURE 12b. INDIVIDUAL PLOTS OF 2 NMI LEFT OFFSET (TSCT VS. FTE)

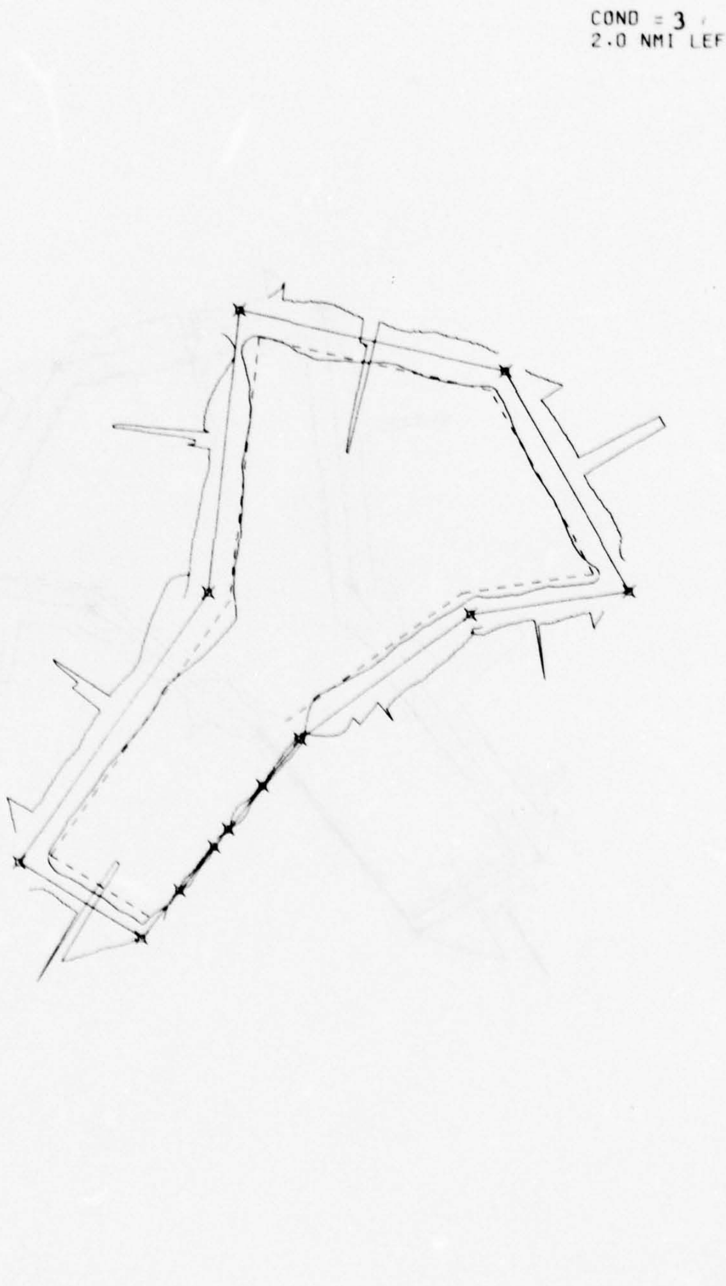

FIGURE 12c. INDIVIDUAL PLOTS OF 2 NMI LEFT OFFSET (TSCT VS. FTE)

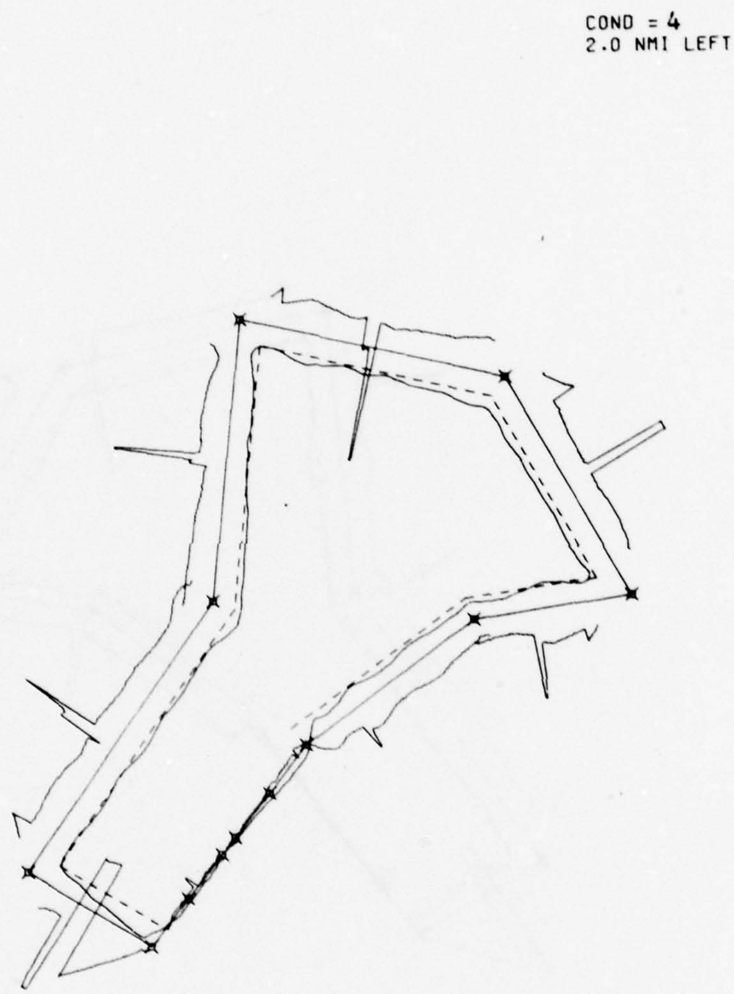

FIGURE 12d. INDIVIDUAL PLOTS OF 2 NMI LEFT OFFSET (TSCT VS. FTE)

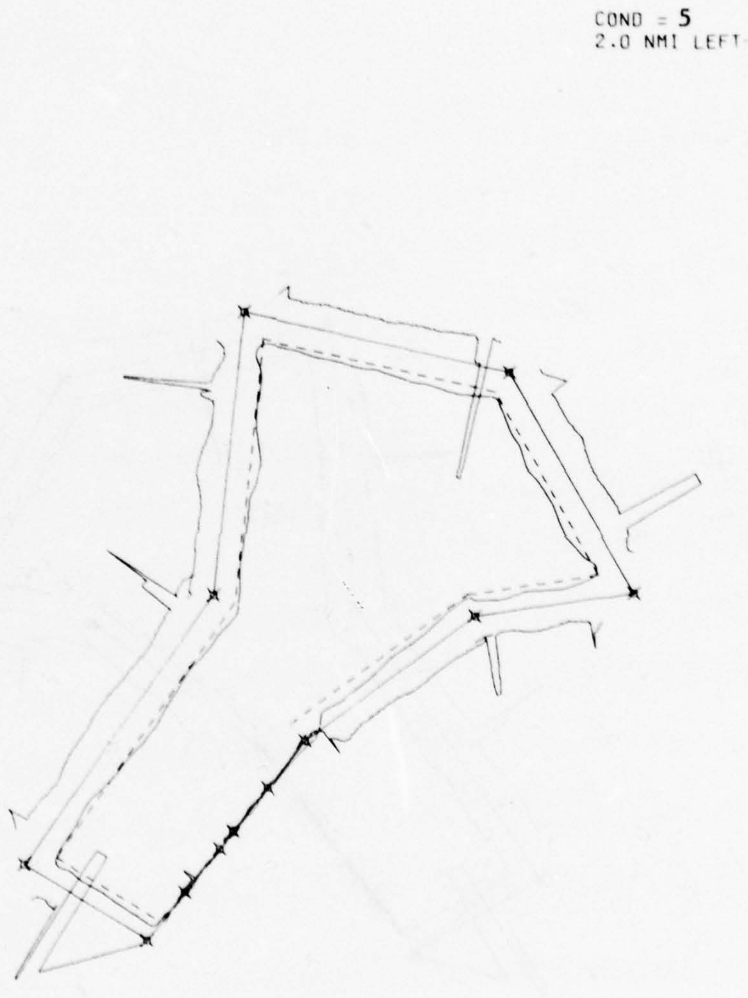

FIGURE 12e. INDIVIDUAL PLOTS OF 2 NMI LEFT OFFSET (TSCT VS. FTE)

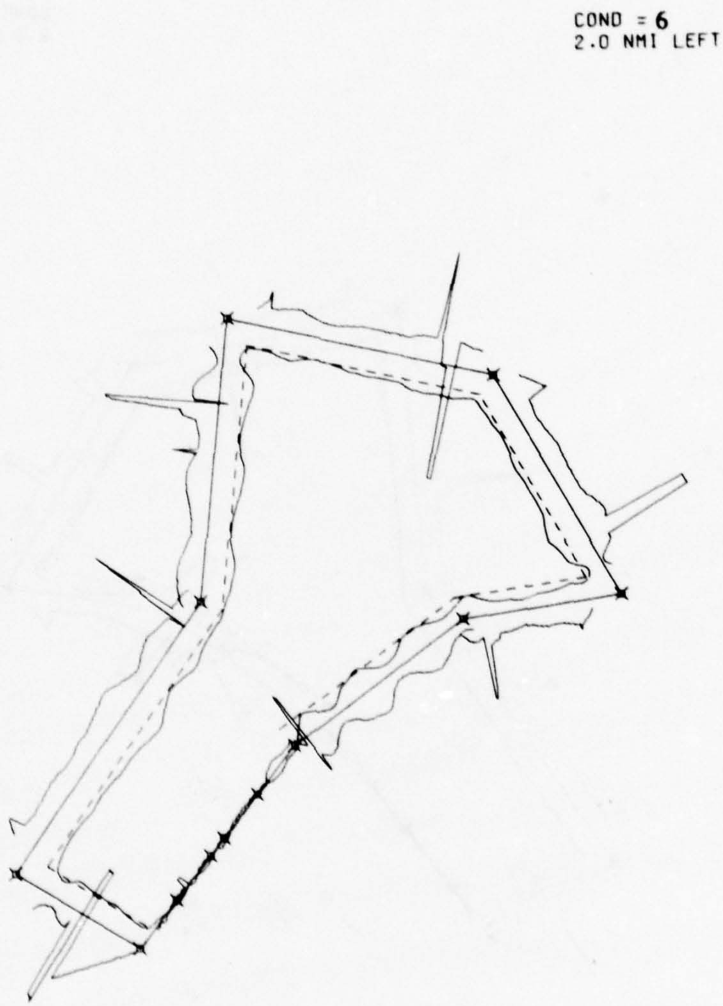

FIGURE 12f. INDIVIDUAL PLOTS OF 2 NMI LEFT OFFSET (TSCT VS. FTE)

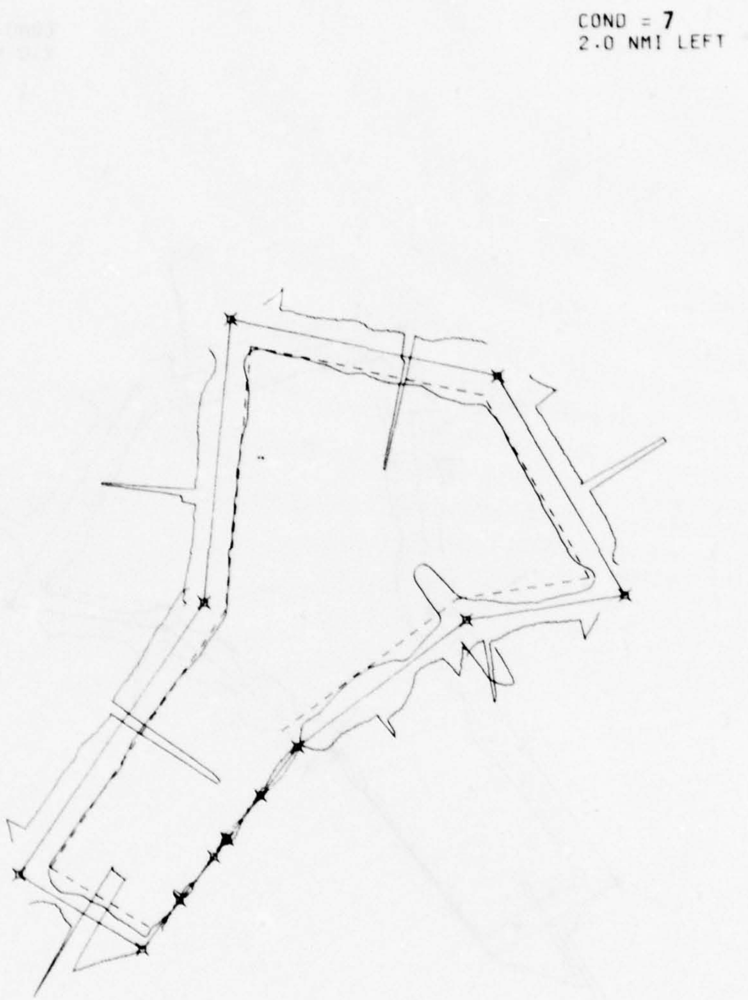

FIGURE 12g. INDIVIDUAL PLOTS OF 2 NMI LEFT OFFSET (TSCT VS. FTE)

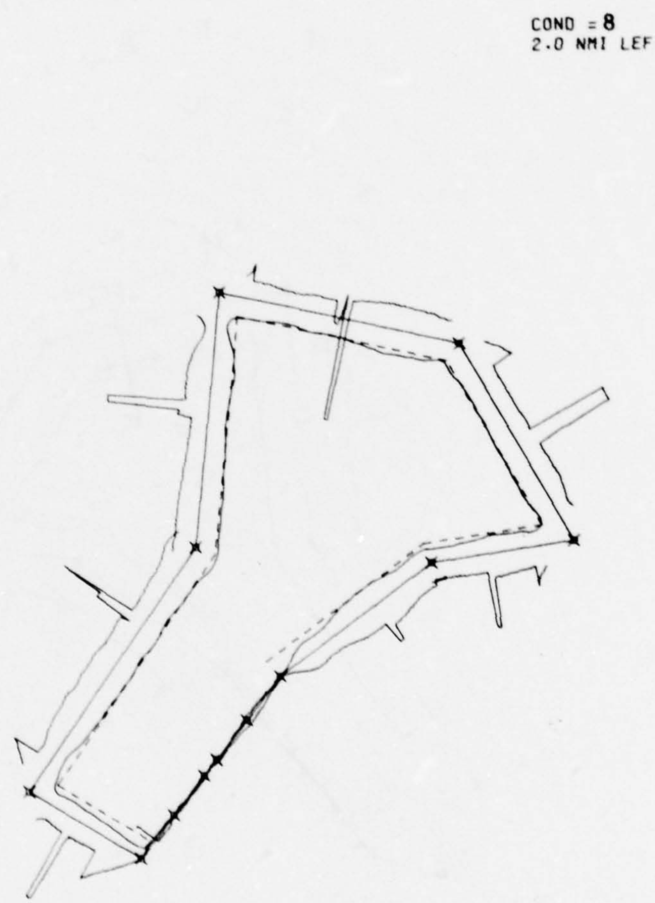

FIGURE 12h. INDIVIDUAL PLOTS OF 2 NMI LEFT OFFSET (TSCT VS. FTE)

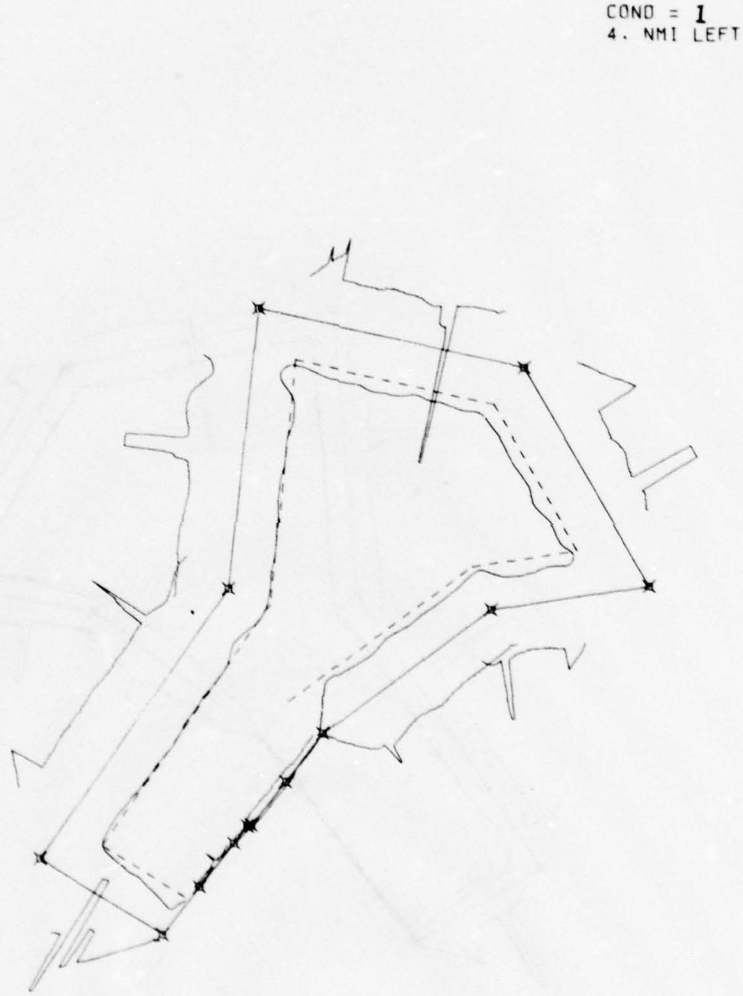

FIGURE 13a. INDIVIDUAL PLOTS OF 4 NMI LEFT OFFSET (TSCT VS.FTE)

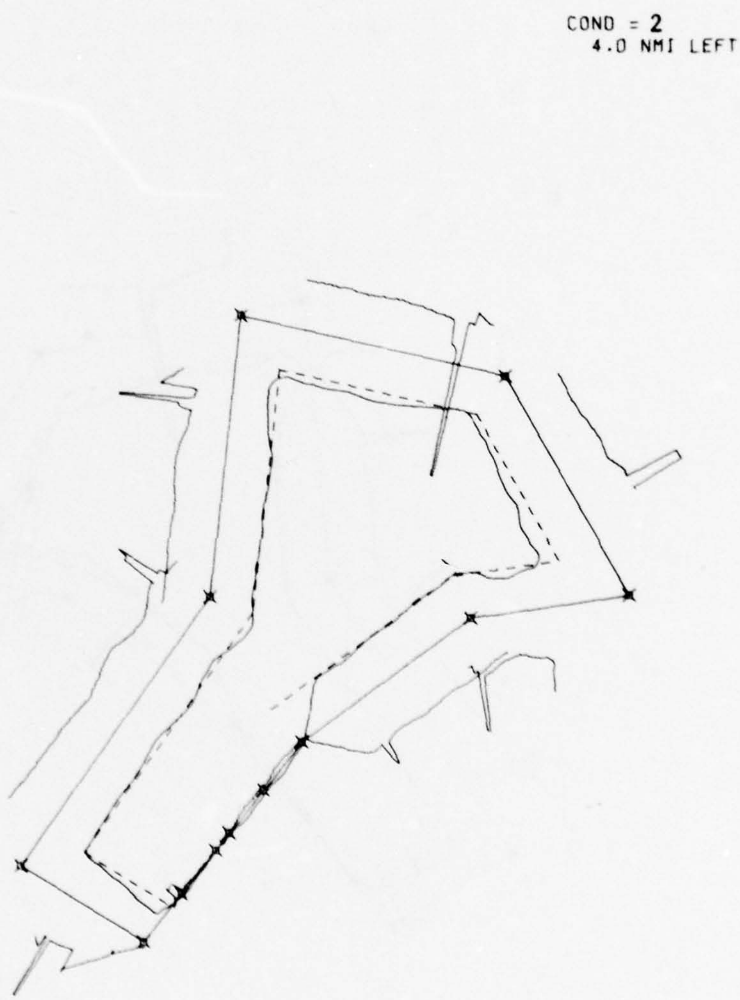

FIGURE 13b. INDIVIDUAL PLOTS OF 4 NMI LEFT OFFSET (TSCT VS. FTE)

FIGURE 13c. INDIVIDUAL PLOTS OF 4 NMI LEFT OFFSET (TSCT VS. FTE)

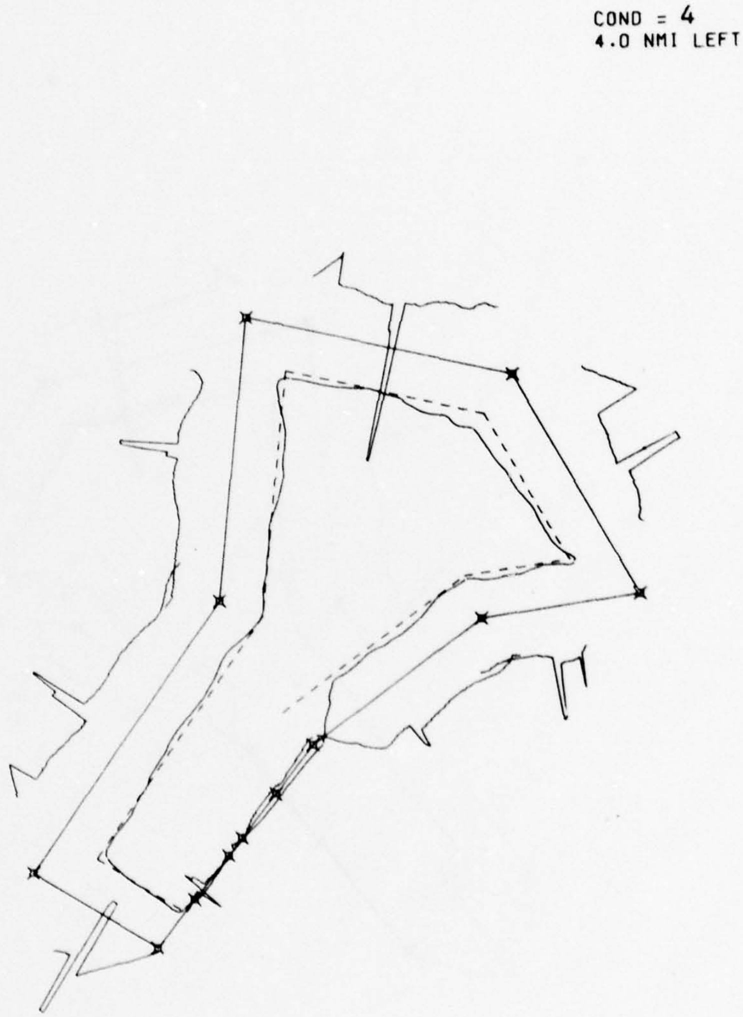

FIGURE 13d. INDIVIDUAL PLOTS OF 4 NMI LEFT OFFSET (TSCT VS. FTE)

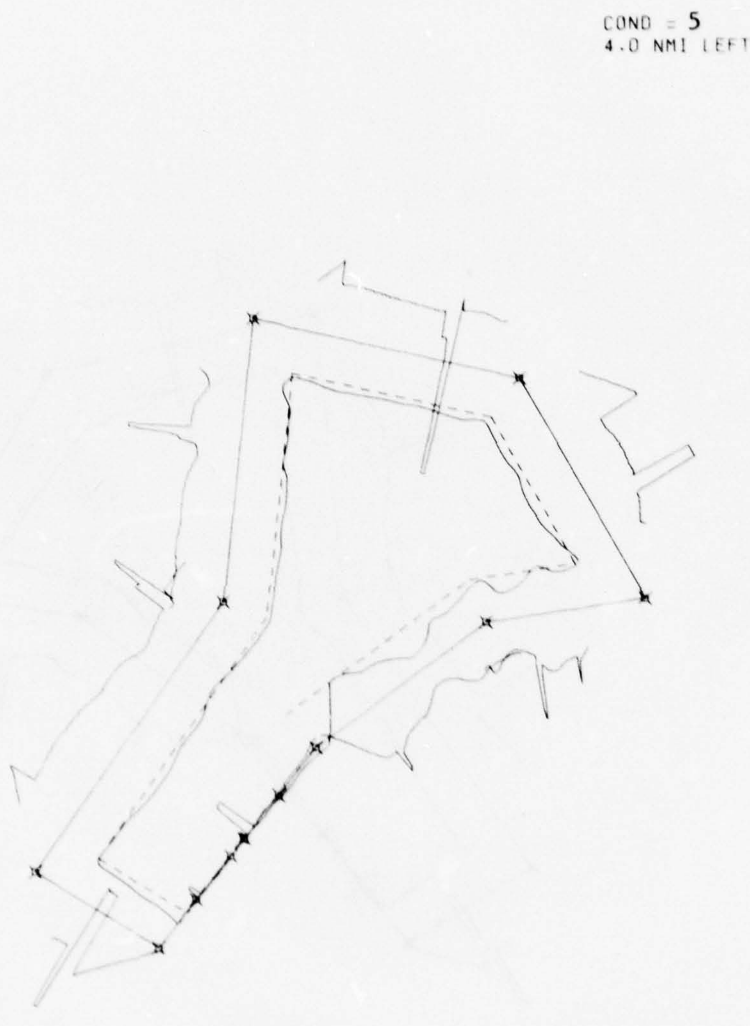

FIGURE 13e. INDIVIDUAL PLOTS OF 4 NMI LEFT OFFSET (TSCT VS. FTE)

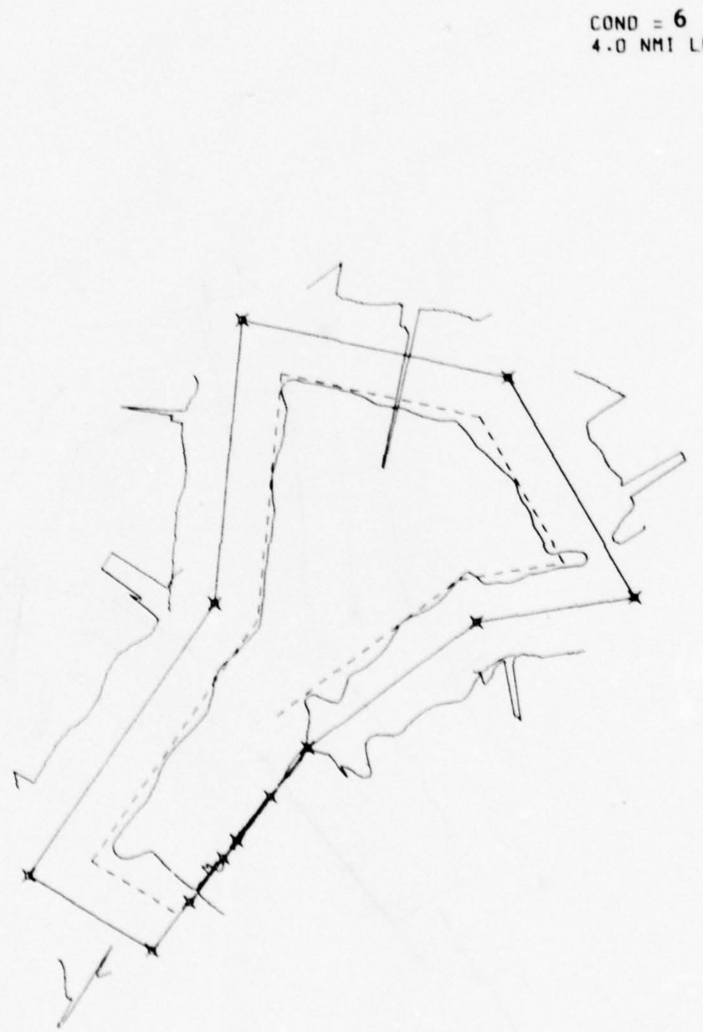

FIGURE 13f. INDIVIDUAL PLOTS OF 4 NMI LEFT OFFSET (TSCT VS. FTE)

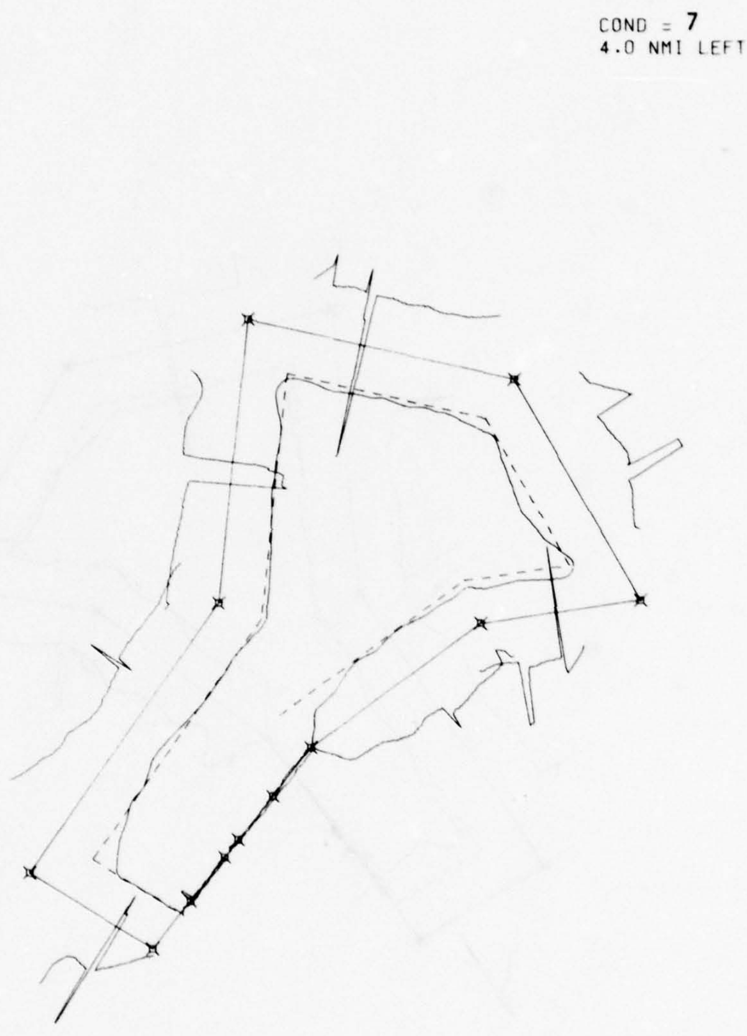

FIGURE 13g. INDIVIDUAL PLOTS OF 4 NMI LEFT OFFSET (TSCT VS. FTE)

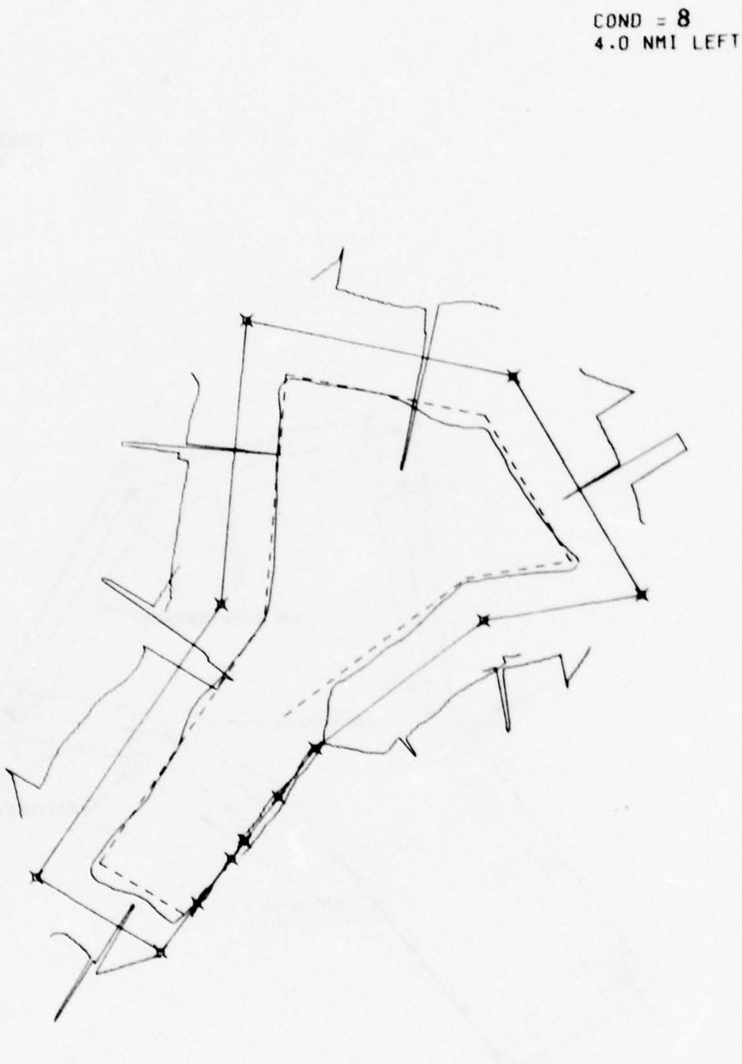

FIGURE 13h. INDIVIDUAL PLOTS OF 4 NMI LEFT OFFSET (TSCT VS. FTE)

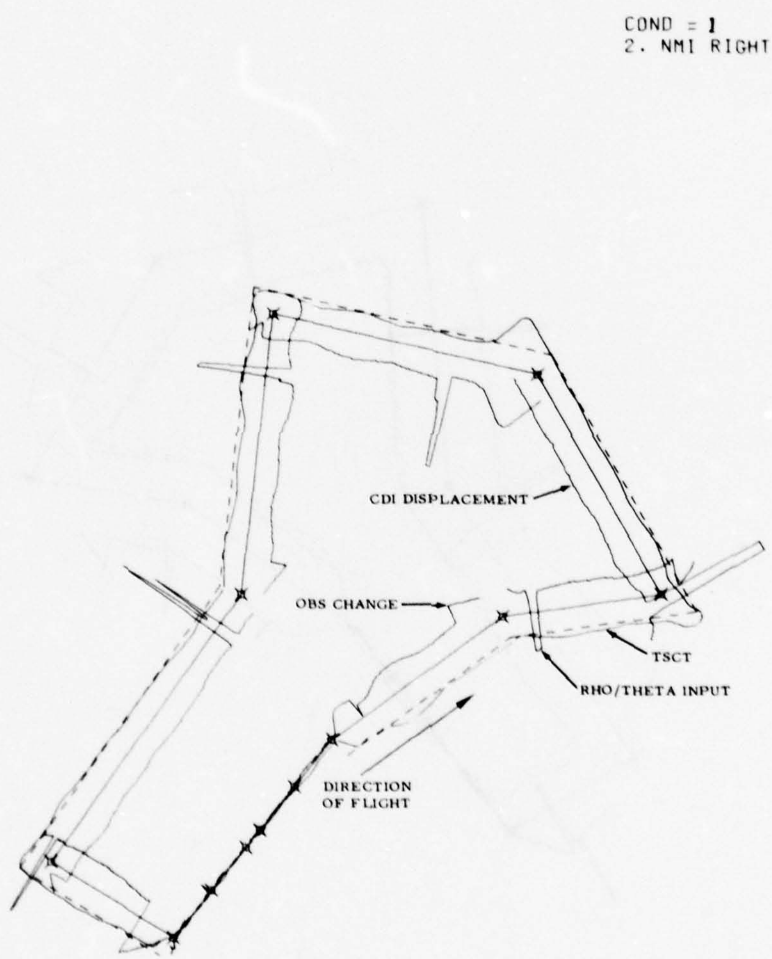

FIGURE 14a. INDIVIDUAL PLOTS OF 2 NMI RIGHT OFFSET (TSCT VS. FTE)

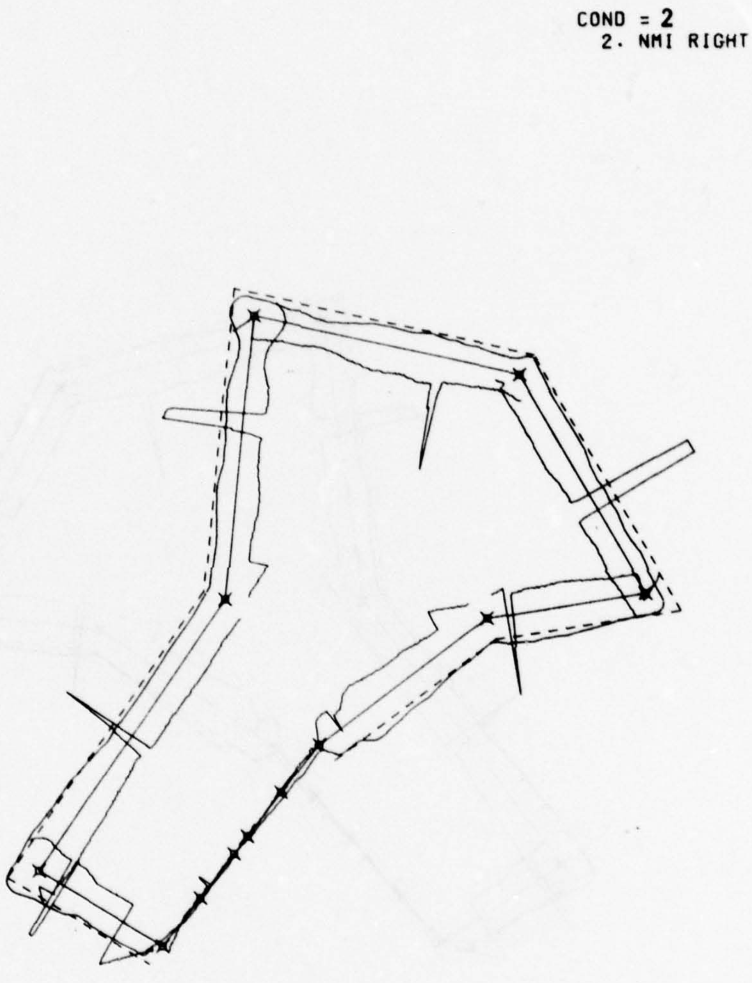

FIGURE 14b. INDIVIDUAL PLOTS OF 2 NMI RIGHT OFFSET (TSCT VS. FTE)

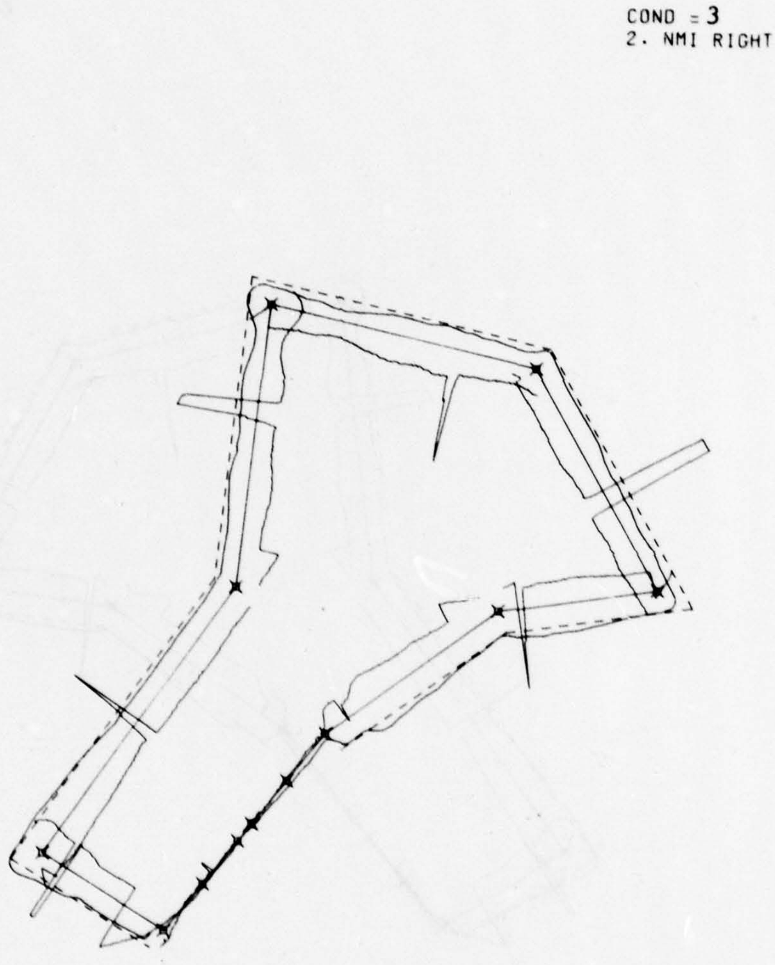

FIGURE 14c. INDIVIDUAL PLOTS OF 2 NMI RIGHT OFFSET (TSCT VS. FTE)

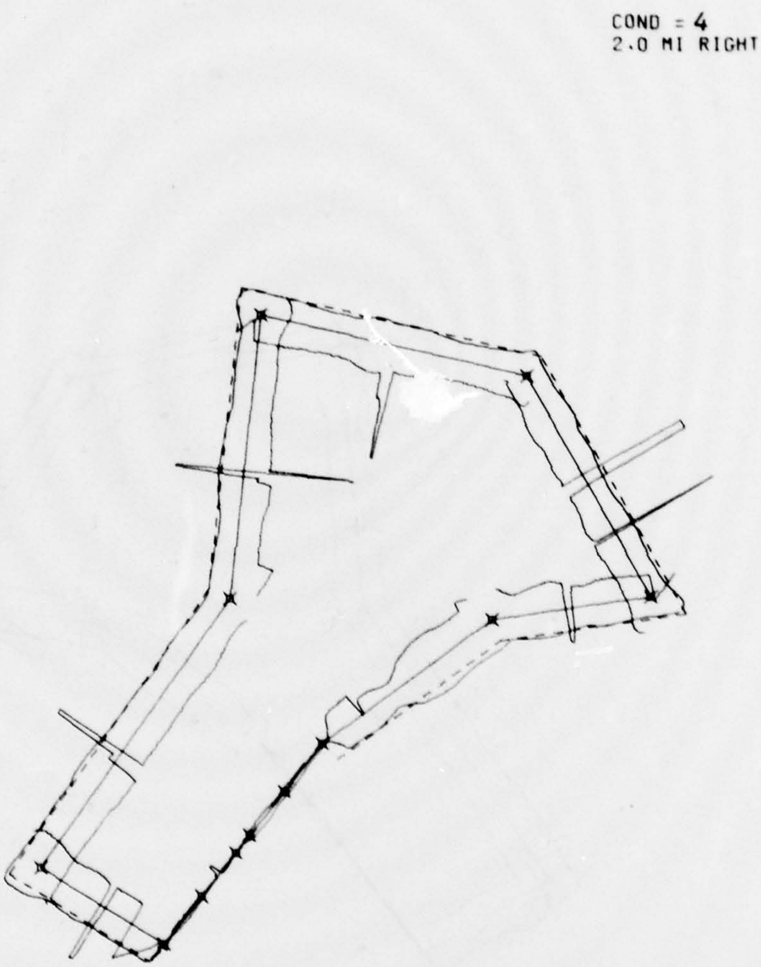

FIGURE 14d. INDIVIDUAL PLOTS OF 2 NMI RIGHT OFFSET (TSCT VS. FTE)

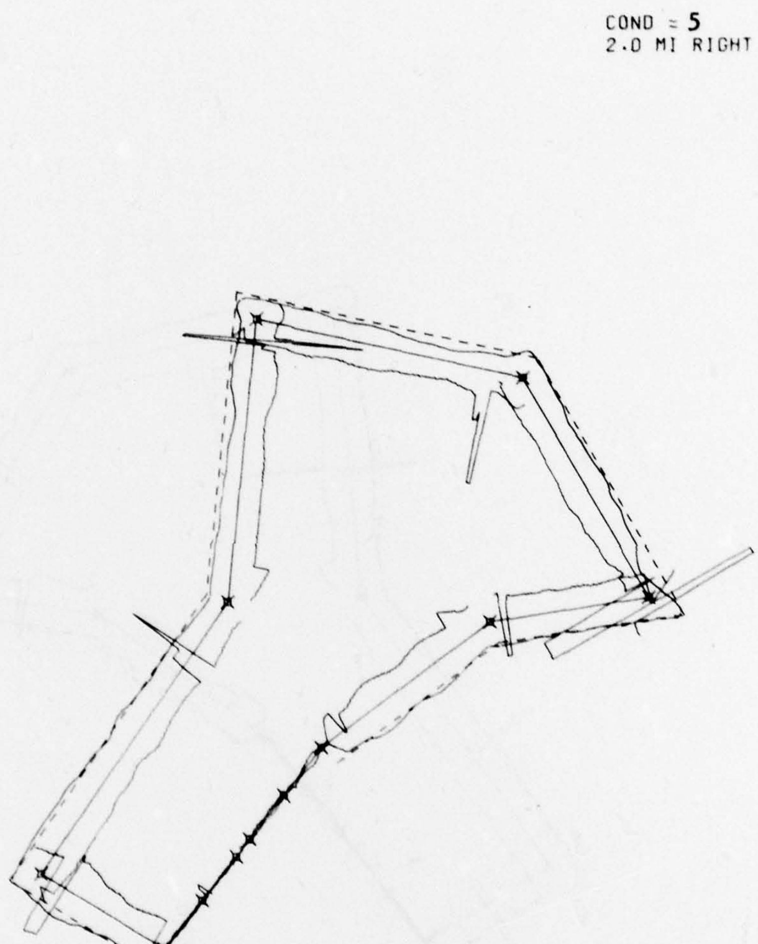

FIGURE 14e. INDIVIDUAL PLOTS OF 2 NMI RIGHT OFFSET (TSCT VS. FTE)

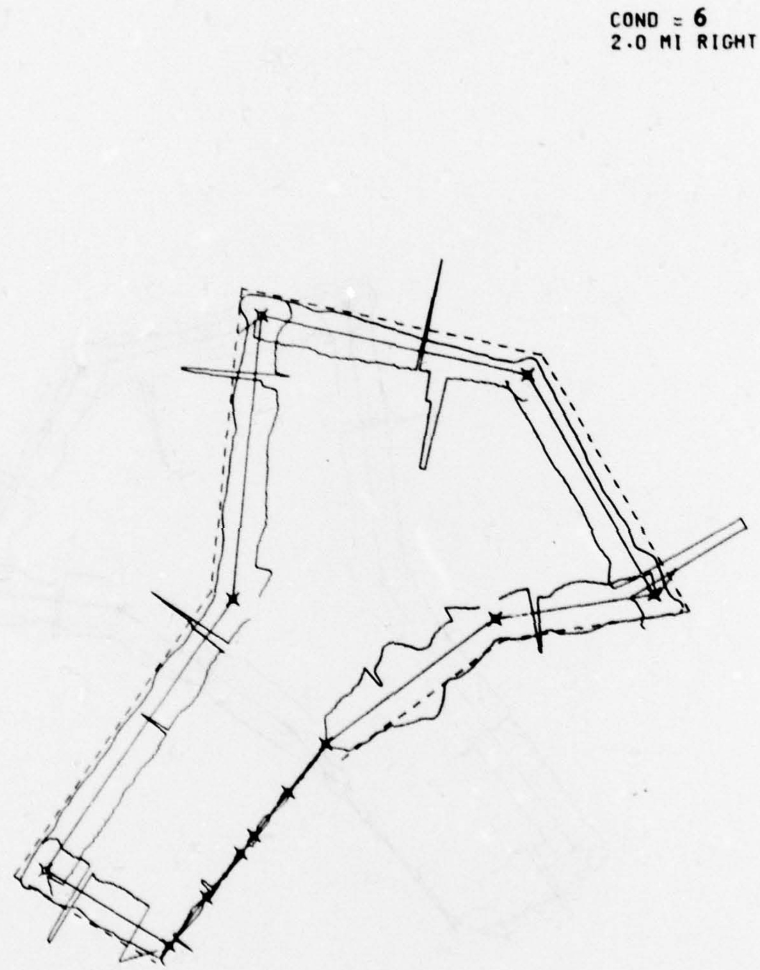

FIGURE 14f. INDIVIDUAL PLOTS OF 2 NMI RIGHT OFFSET (TSCT VS. FTE)

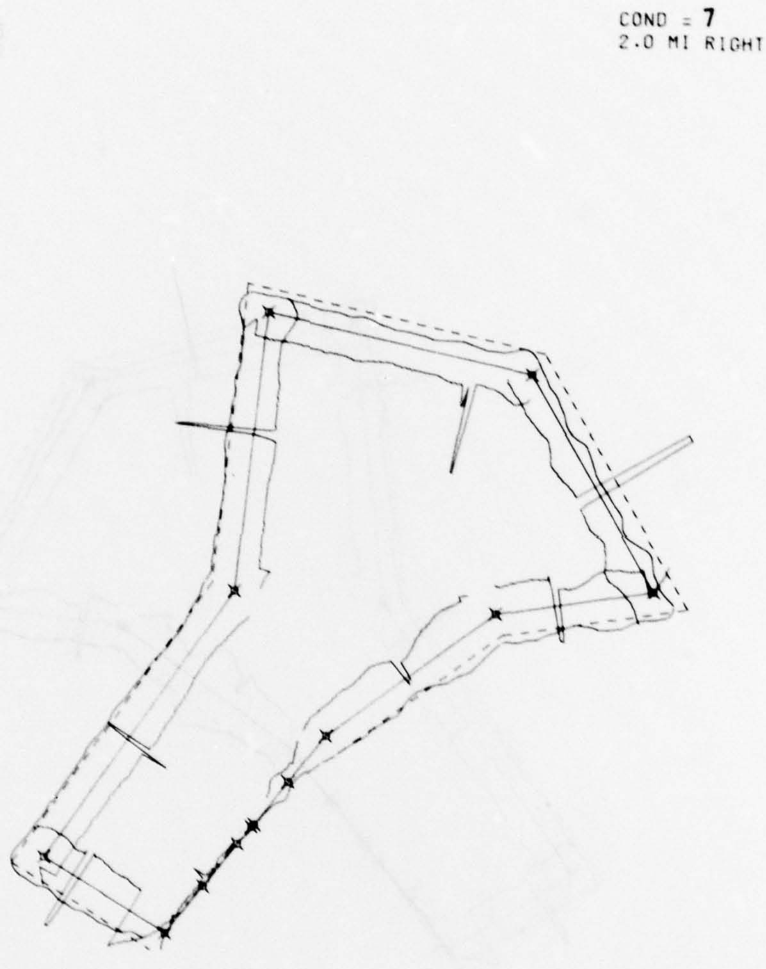

FIGURE 14g. INDIVIDUAL PLOTS OF 2 NMI RIGHT OFFSET (TSCT VS. FTE)

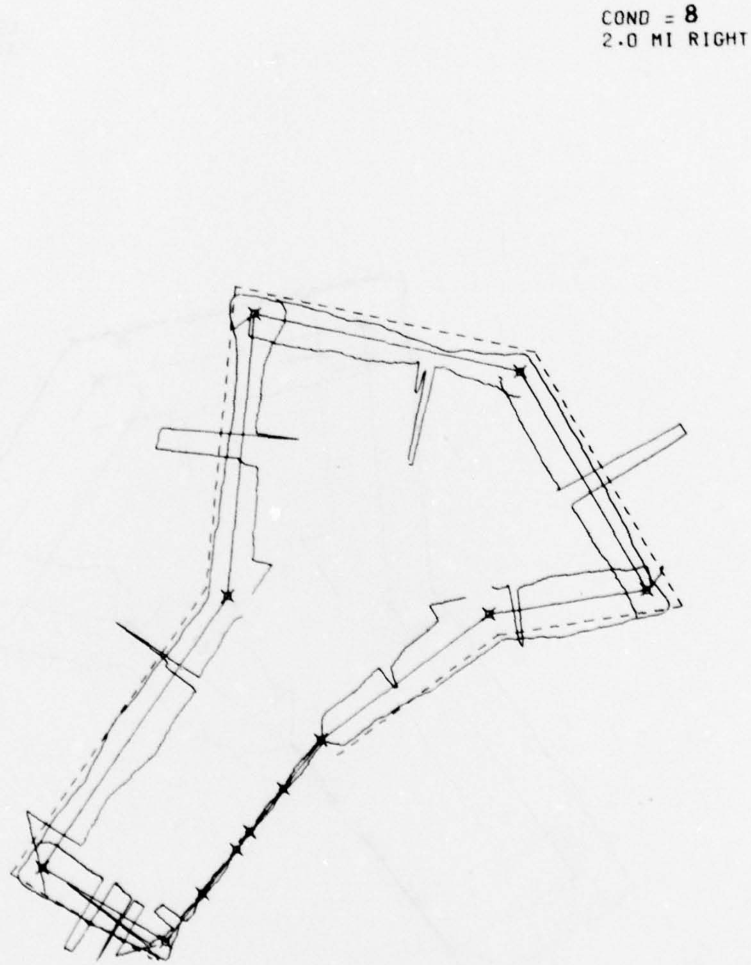

FIGURE 14h. INDIVIDUAL PLOTS OF 2 NMI RIGHT OFFSET (TSCT VS. FTE)

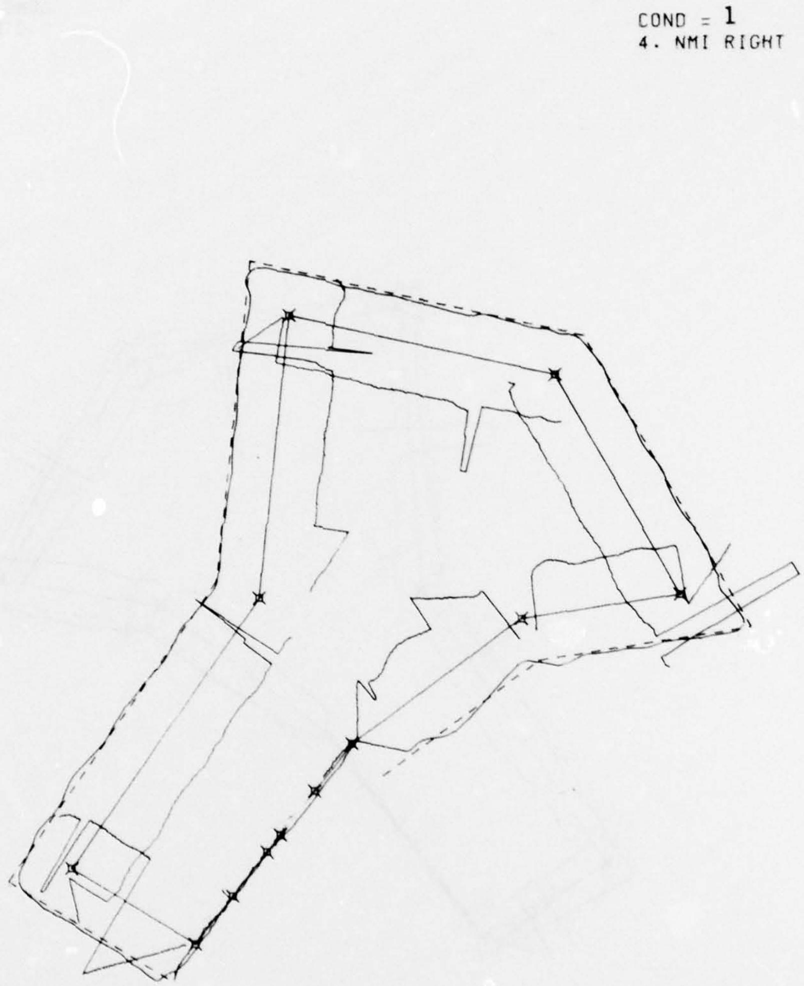

FIGURE 15a. INDIVIDUAL PLOTS OF 4 NMI RIGHT OFFSET (TSCT VS. FTE)

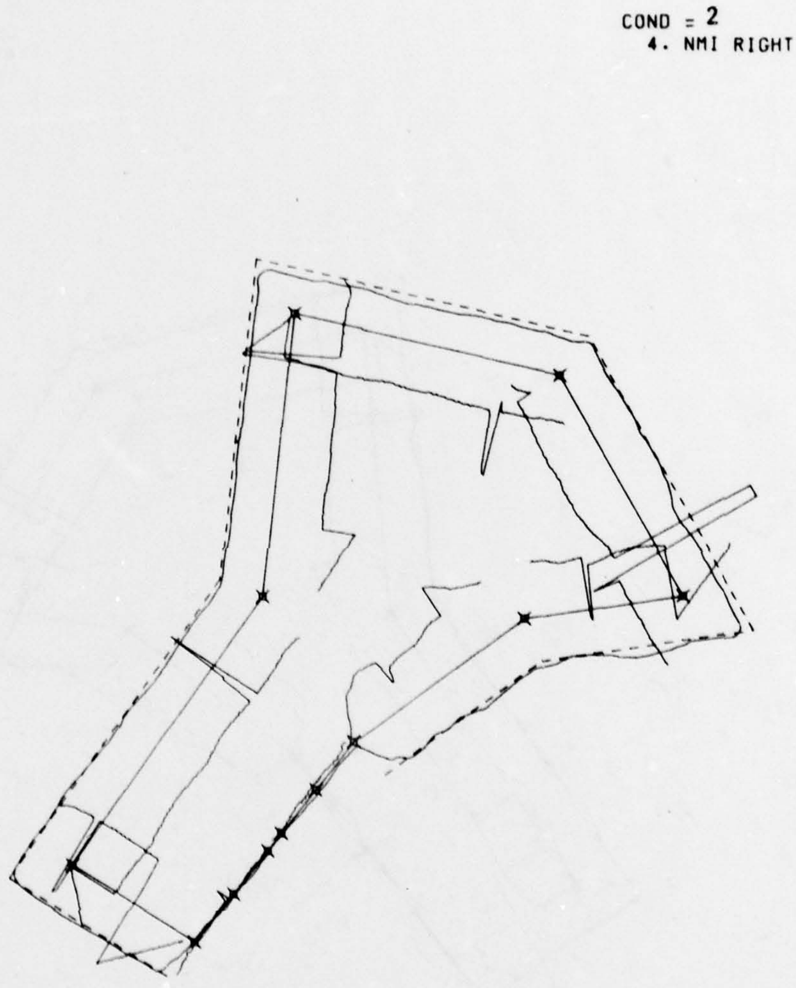

FIGURE 15b. INDIVIDUAL PLOTS OF 4 NMI RIGHT OFFSET (TSCT VS. FTE)

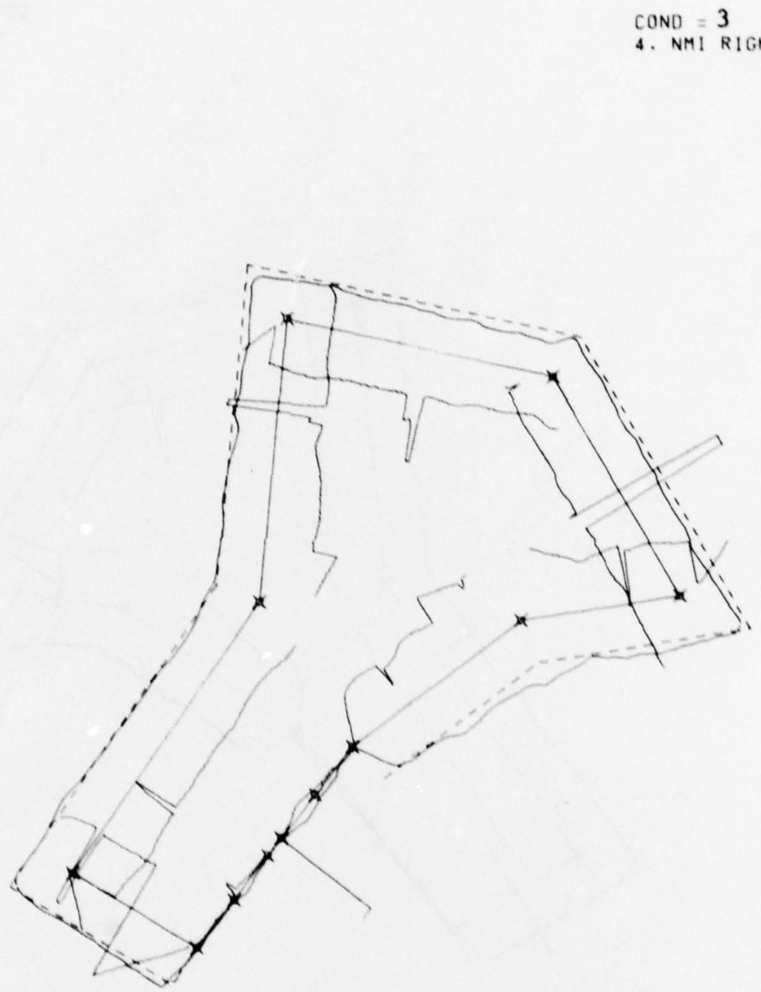

FIGURE 15c. INDIVIDUAL PLOTS OF 4 NMI RIGHT OFFSET (TSCT VS. FTE)

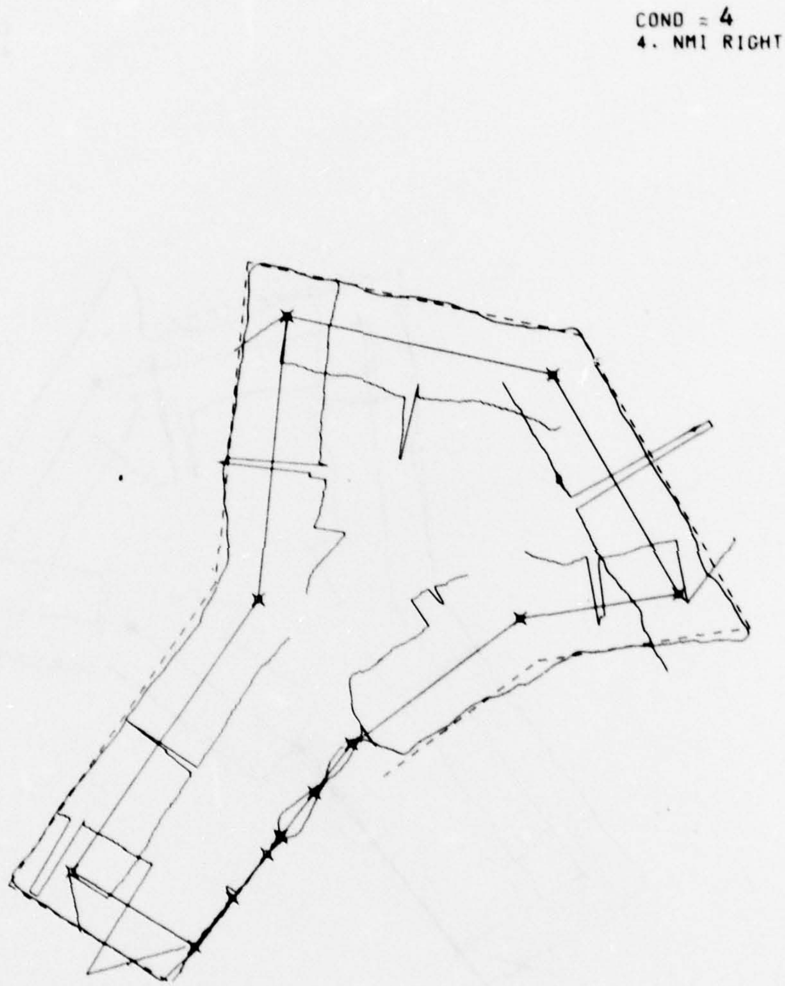

FIGURE 15d. INDIVIDUAL PLOTS OF 4 NMI RIGHT OFFSET (TSCT VS. FTE)

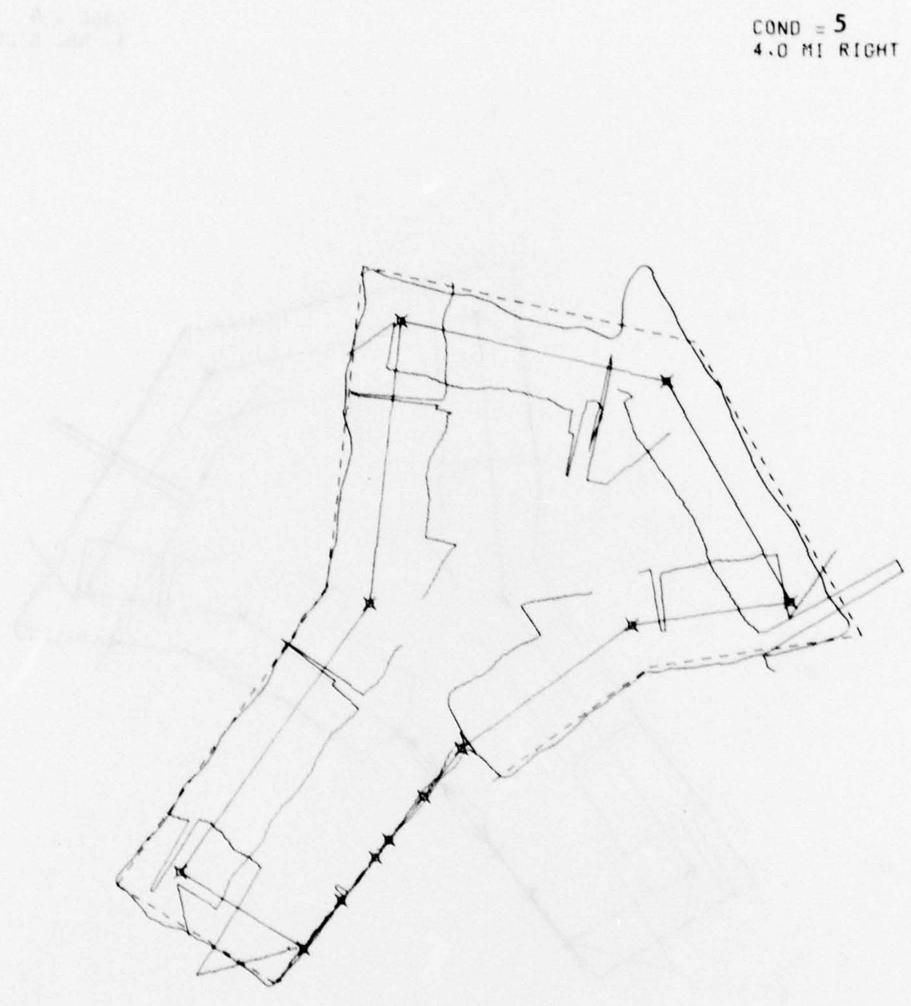

FIGURE 15e. INDIVIDUAL PLOTS OF 4 NMI RIGHT OFFSET (TSCT VS. FTE)

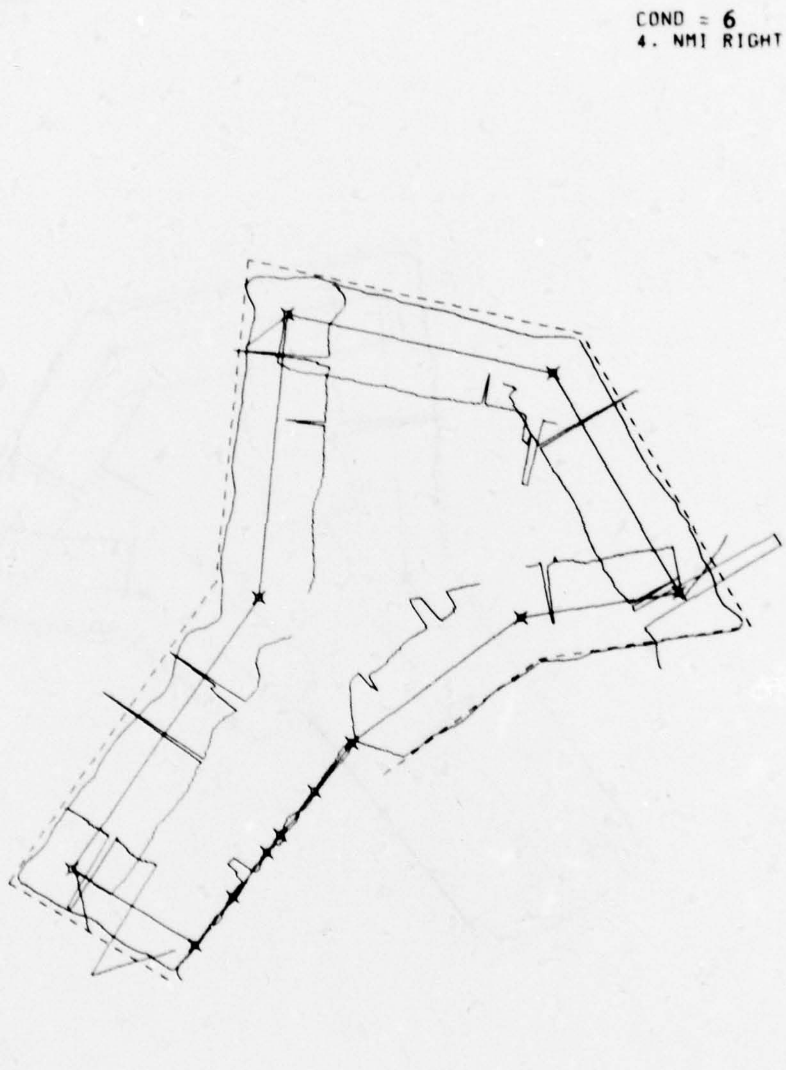

FIGURE 15f. INDIVIDUAL PLOTS OF 4 NMI RIGHT OFFSET (TSCT VS. FTE)

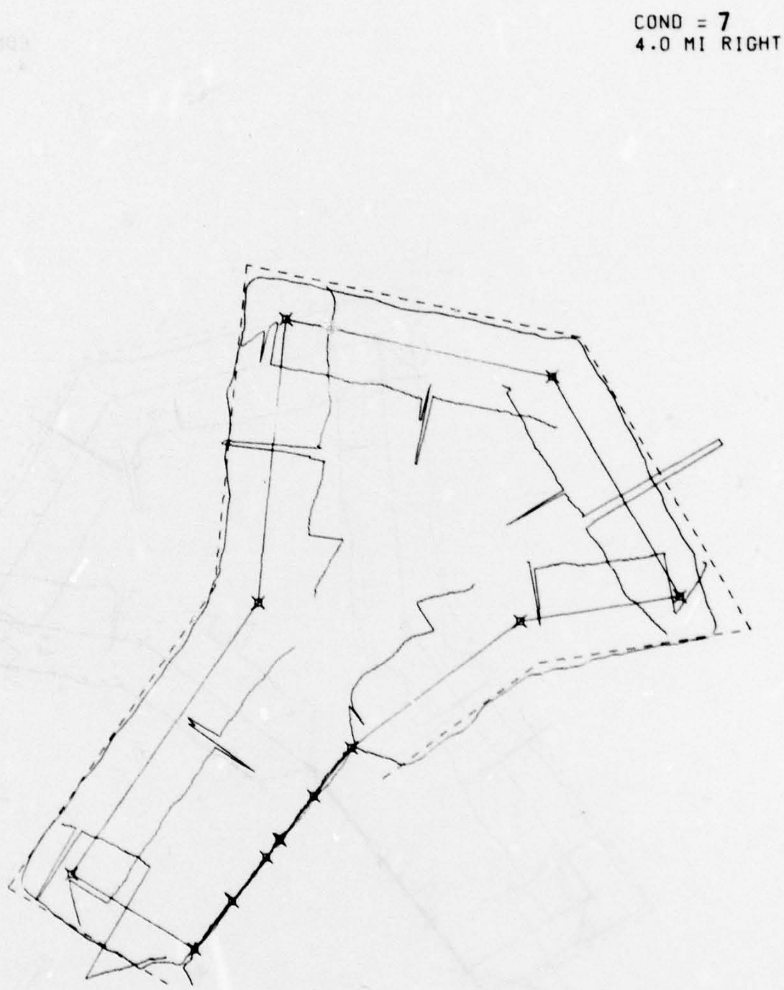

FIGURE 15g. INDIVIDUAL PLOTS OF 4 NMI RIGHT OFFSET (TSCT VS. FTE)

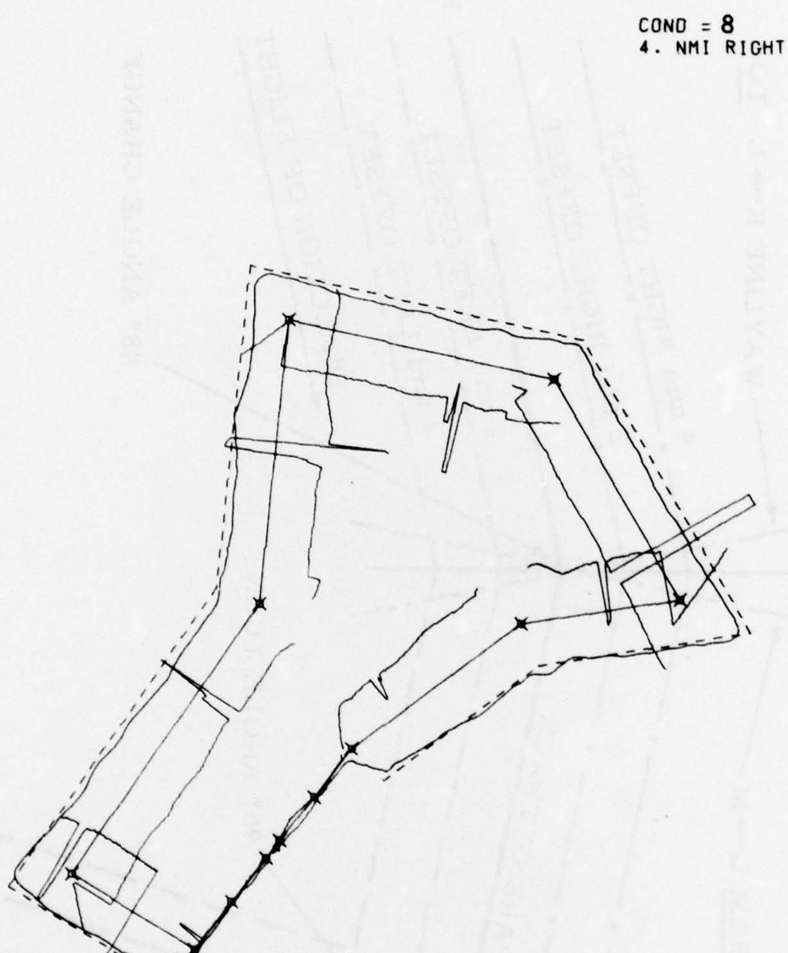

FIGURE 15h. INDIVIDUAL PLOTS OF 4 NMI RIGHT OFFSET (TSCT VS. FTE)

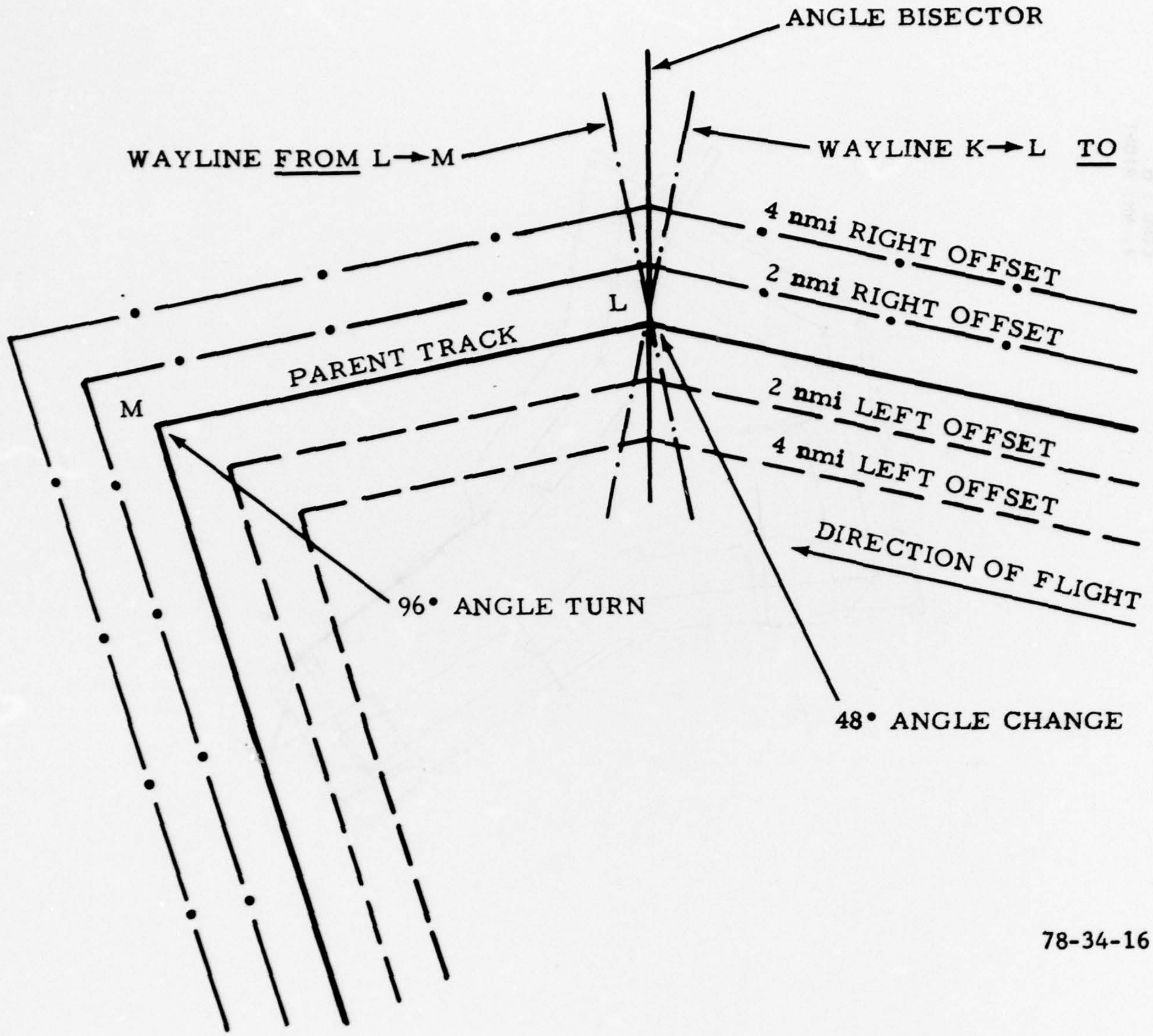

FIGURE 16. DIAGRAM OF TRANSITION AT WAYPOINT L